NASA-TM-108699

188 P.

# RESEARCH AND TECHNOLOGY ADVISORY COUNCIL,

AD HOC PANEL ON TERMINAL

CONFIGURED VEHICLES

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REVIEW

NASA

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## REPORT OF MEETING

July 21-22, 1976

(NASA-TM-108699) RESEARCH AND TECHNOLOGY ADVISORY COUNCIL, AD HOC PANEL ON TERMINAL CONFIGURED VEHICLES: REPORT OF MEETING (NASA) 188 p

N93-71967

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Z9/05 0152174

OFFICE OF AERONAUTICS & SPACE TECHNOLOGY

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

## SUMMARY

The Fourth Meeting of the NASA Research and Technology Advisory Council, Ad Hoc Panel on Terminal Configured Vehicles was held on July 21-22, 1976, at the Langley Research Center, Hampton, Virginia. The meeting was open to the public.

The Panel took the following actions:

1. Recommended a revision of the goal, major objectives, and areas of emphasis for the Terminal Configured Vehicle Program.

2. Resolved that the Panel supports the ongoing NASA-Langley oculometer research and suggests that this effort has considerable potential in developing new cockpit display arrangements including advanced display concepts and for flight training improvement.

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## APPENDICES

NASA RESEARCH AND TECHNOLOGY ADVISORY COUNCIL

PANEL ON AERONAUTICAL SAFETY AND OPERATING SYSTEMS

AD HOC PANEL ON TERMINAL CONFIGURED VEHICLES

Hampton, Virginia
July 21-22, 1976

MEMBERS IN ATTENDANCE

Chairman - Mr. John Gorham - Gorham Associates

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|---|---|
| Mr. James P. Andersen | Transportation Systems Center |
| Captain Larry DeCelles | Air Line Pilots Association |
| Mr. Ralph L. Erwin, Jr. | Boeing Commercial Airplane Co. |
| Captain George T. Henderson | United Air Lines, Inc. |
| Mr. Ronald S. Hersh | Federal Aviation Admin. |
| Mr. George B. Litchford | Litchford Associates |
| Mr. Paul H. Patten | Douglas Aircraft Co. |
| Mr. Siegbert B. Poritzky | Air Transport Assn. |
| Mr. Robert S. Stahr | Eastern Airlines, Inc. |

Ex Officio Members Present:

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|---|---|
| Mr. Brent Y. Creer | Ames Research Center |
| Mr. John P. Reeder | Langley Research Center |
| Mr. James E. Stitt | Langley Research Center |

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| Mr. Kenneth E. Hodge<br>Executive Secretary | NASA Headquarters |
| Mr. Lee D. Goolsby<br>Recording Secretary | NASA Headquarters |

Invited Guests and Visitors:

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|---|---|
| Mr. Frank Wright | Lockheed Aircraft |
| Brig. Gen. James H. Marshall, USAF | Air Force Systems Command |
| Mr. W. J. Cox | Federal Aviation Admin. |
| Mr. Harry Verstynen | Federal Aviation Admin. |
| Mr. E. G. Lyman | NASA Headquarters |
| Mr. Alan Chambers | Ames Research Center |
| Mr. Jules I. Kanter | ACLS Corporation |
| Mr. Robert T. Taylor | Langley Research Center |
| Mr. Ernest W. Millen | Langley Research Center |
| Mr. Howard V. Seal | Boeing Commercial Airplane Co. |
| Mr. W. L. Hyland | Federal Aviation Admin. |
| Mr. Paul M. Rich | Federal Aviation Admin. |
| Col. H. G. Tinsley, USAF | Federal Aviation Admin. |
| Mr. M. E. Perie | Federal Aviation Admin. |
| Mr. N. A. Blake | Federal Aviation Admin. |
| Mr. D. M. Fadden | Boeing Commercial Airplane Co. |
| Mr. A. R. Mulally | Boeing Commercial Airplane Co. |
| Mr. Bruce Florsheim | Boeing Commercial Airplane Co. |
| Mr. R. T. Duffy | Wallops Flight Center |
| Mr. J. D. Howell | Air Line Pilots Assn. |
| Mr. Lee Person | Langley Research Center |
| Dr. Charlie Knox | Langley Research Center |
| Mr. Sam Morello | Langley Research Center |
| Mr. Hewitt Phillips | Langley Reserach Center |
| Mr. George Steinmetz | Langley Research Center |
| Mr. Amos Spady | Langley Research Center |
| Mr. Max Kurbjun | Langley Research Center |
| Mr. Leonard Credeur | Langley Research Center |
| Dr. Tom Walsh | Langley Research Center |
| Mr. William D. Mace | Langley Research Center |
| Mr. Tom Bundick | Langley Research Center |
| Mr. Duncan McIver | Langley Research Center |
| Ms. Sandra Chaney | Langley Research Center |
| Mr. S. Salmirs | Langley Research Center |
| Mr. Eugene Shult | Langley Research Center |

## OPENING REMARKS AND WELCOME

The Panel was welcomed to the Langley Research Center by Mr. James E. Stitt, Director for Electronics. Chairman Gorham also welcomed members and visitors to the meeting.

## APPROVAL OF MINUTES

The minutes of the previous meeting were approved as written.

## EXECUTIVE SECRETARY's REPORT

Mr. Kenneth E. Hodge reviewed recent changes in the NASA Headquarters organization and key personnel changes affecting OAST. Dr. Lovelace is now Deputy Administrator of NASA.

Mr. Robert E. Smylie is Acting Associate Administrator for Aeronautics and Space Technology and Dr. James J. Kramer is Acting Deputy Associate Administrator, OAST. Dr. Kramer remains also as Director, Aircraft Energy Efficiency Division.

Mr. Hodge showed some charts which depicted NASA budget trends during recent years showing the continuing growth in the NASA aeronautics program.

## CHAIRMAN's REPORT

Mr. Gorham informed the Panel members that the formal recommendations resulting from previous meeting in September had been approved by the parent committee. He stated that Mr. Stitt, Mr. Reeder and their staffs, have been making an earnest effort to follow the recommendations and in defining a TCV program responsive to the Panel recommendations. The Chairman had worked closely with TCV program management personnel between Panel meetings and had kept the Panel members informed of their progress in defining the TCV program. He had requested Panel members to submit comments to him on the program content. He reported that most members felt that the strawman program definition had resulted in a program of wider scope than can be carried out with available resources in the next few years. During the course of this Panel meeting, an attempt will be made to pare down the goals and tasks to something more manageable and realistic.

Review and Discussion of Upgraded Goals and Objectives of The Terminal Configured Vehicle Program: At a meeting of the Panel on Aeronautical Operating Systems on October 29-30, 1975, it was recommended "that the near-, mid-, and long-term objectives of the TCV program be more clearly defined in the context of current as well as future aircraft systems compatibility and the research goals of the TCV program". Mr. Reeder presented NASA's response to this recommendation. The TCV programs goals, objectives, and areas of emphasis as defined by the TCV Program Office at Langley are as follows:

TCV Program Goals: Provide CTOL aircraft and flight management technology that will benefit terminal area operations.

The major objectives to achieve the goal are:

I. Improve terminal area capacity and efficiency.

II. Improve approach and landing capability in adverse weather.

III. Reduce noise impact through operating procedures.

Areas of Emphasis:

I. Improve terminal area capacity and efficiency.

A. Airborne systems and procedures which aid in the evaluation of, and provide supporting information for ATC system evolution (cooperation with FAA):

1. Define and evaluate transition techniques and maneuvers from RNAV to MLS guidance through landing that will permit close-in MLS acquisition, including downwind entry, and stabilized flight within MLS coverage.

2. Examine techniques and configurations for maximum utilization of MLS-provided information and simplification of onboard system interfaces and sensor requirements.

3. Define and evaluate advanced profiles and flight procedures for fuel conservation, noise alleviation, pilot and passenger acceptance, airspace productivity, operational flexibility and ATC compatibility.

4. Evaluate displays, procedures and options for crew participation in traffic control which could improve safety in congested air space or add capacity to the ATC system.

5. Explore simplified crew interfaces with ATC, including better ways to display navigation and clearance communications for the pilots' rapid assimilation and assessment.

B. Airborne systems and procedures for increased runway capacity:

1. Demonstrate curved-path following that could permit reduced runway separation requirements for simultaneous approaches through reduction of overshoot and tracking errors.

2. Investigate the degree to which aircraft configuration and procedural changes could reduce longitudinal separation and enhance the runway feeding process.

3. Explore the use of EL-2 for landing guidance to reduce longitudinal touchdown dispersion.

4. Explore the reduction of runway occupancy time through controlled automatic braking, guided high-speed turnoff, improved aircraft ground-handling qualities, and appropriate pilot displays.

II. Improved approach and landing capability in adverse weather

A. Human factor elements that contribute to effective flight management operations.

1. Investigate combinations of automated functions and piloting tasks that command major crew attention entail excessive workload, or require special training to achieve effective flight management performance.

2. Explore critical information needs and decision processes for crew intercedance during man/machine/environment interactions, including transition to outside cues for landing in very poor visibility (cooperation with Ames).

3. Evaluate display requirements, including format, field of view, motion cues, and real-world perspective, for approach, landing, roll-out, high-speed turnoff and taxi operations in very poor visibility (cooperation with Ames).

4. Explore simplified computer-address technique, including methods for direct entry of navigation way-point data into a display (cooperation with Ames)

B. Effective combinations of displays, automatic controls and procedures for performing precision approach and landing operations under poor visibility conditions.

1. Explore and define approach and landing display requirements in term of data sources, techniques for data presentation and redundancy options.

2. Reduce wind shear effects through predictive techniques in autoland design and by displaying information for pilot thrust management and flight path control.

3. Investigate flight path control concepts and operating procedures to improve handling qualities, flight path precision, and productivity of airborne operations.

4. Examine critical elements of the airborne system, including the crew, displays, automatic control and navigation systems, and define hardware and software techniques, revision modes, and validation and monitoring requirements leading to improved reliability of system simplification.

5. Determine the weather-penetrating potential of airborne sensor technology.

III. Reduce Noise in the Terminal Area Through Operating Procedures

A. Effective flight profiles and configurations:

1. Examine effect of curved paths (within MLS coverage) on noise footprint and distribution.

2. Examine effect of decelerating techniques (thrust and configuration) on noise footprint and level.

3. Explore higher angle approaches achieved through use of advanced automatic controls and pilot displays.

4. Evaluate the potential of powered wheels for taxi operations.

Discussion:

Panel members had been given a copy of the above goals and objectives prior to the meeting and were prepared to make positive recommendations on each item. It was agreed that "terminal area operations" should commence from the start of letdown. After considerable discussion the Panel recommended that the TCV Program Objectives be revised as follows:

TCV Program Goal:

Identify aircraft and flight management technology that will benefit CTOL terminal area operations.

The Major Objectives to Achieve the Goal are:

Conduct research that will support improvements in:

I. Terminal area capacity and efficiency.

II. Approach and landing capability in adverse weather.

III. Reduction of Noise Impact.

Areas of Emphasis:

I. Improve terminal area capacity and efficiency

A. Airborne systems and procedures which aid in the evaluation of, and provide supporting information for, ATC system evolution(cooperation with FAA):

1. Define and evaluate transition techniques and maneuvers through landing that will permit close-in acquisition of runway heading including downwind entry, and stabilized flight within MLS coverage ensuring maximum simplification of onboard system interfaces and sensor requirements.

2. Examine the noise characteristics and potential noise reduction of aircraft utilizing curved paths in congested terminal areas.

3. Examine the minimum (simplest acceptable) and optimum arrangement of information and displays to help pilots achieve confidence on the safety and satisfactory execution of complex approach paths, flown either manually or automatically.

4. Respond to FAA recommendations in research efforts which could result in safe maximum utilization of congested air space or add capacity to the ATC system including simplified crew interfaces with ATC, and better ways to display navigation and clearance communications for the pilots' rapid assimilation and assessment.

B. Airborne systems and procedures for increased runway capacity:

1. Demonstrate curved-path following that could permit reduced runway separation requirements for simultaneous approaches through reduction of overshoot and tracking errors.

2. Investigate the degree to which aircraft configuration and procedural changes could reduce longitudinal separation and enhance the runway feeding process.

II. Improved approach and landing capability in adverse weather.

A. Human factor elements that contribute to effective flight management operations in cooperation with Ames' human factors program.

1. Explore critical information needs and decision processes for crew participation in terminal area operations, including transition to outside cues for landing in very poor visibility.

2. Evaluate display requirements including format, field of view, motion cues, and real-world perspective, for approach, missed approach, landing, rollout, high-speed turnoff, and taxi operations in very poor visibility.

3. Explore simplified computer-address techniques, including methods for direct entry of navigation way-point data into a display.

B. In response to FAA recommendations conduct research on reduction of wind shear effects by improved autoland design and optimization of information for thrust management and flight path control.

C. Determine the weather-penetrating potential of airborne sensor technology.

III. Reduction of noise impact.

A. Effective flight profiles and configurations:

1. Examine effect of curved paths (within MLS coverage) on noise footprint and distribution.

<u>Major Features of the Upgraded Third Generation Air Traffic Control System:</u>

As one means of complying with the Panel recommendation "that NASA strengthen and maintain its coordination with FAA to ensure that the TCV program will relate to and provide supporting information for air traffic control systems evolution", NASA requested that the Office of Systems Engineering Management, FAA, provide a briefing on features of the Upgraded Third Generation Air Traffic Control System which could impact or be impacted by the TCV program technology.

Mr. Neal Blake, Acting Director of Systems Engineering Management, headed a team of briefers from the FAA. The subjects covered and presenters were:

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|---|---|
| DABS | Mr. William Hyland |
| Control Message Automation | Mr. William Hyland |
| Aircraft Separation Assurance | Mr. William Hyland |
| RNAV | Mr. Paul Rich |
| WVAS and Wind Shear | Col. Guise Tinsley, USAF |

The charts used in these presentations are shown in appendices A through E.

In addition to features of the UG3RD ATC system, some advanced system engineering (long range research) activities were presented as follows:

| | |
|---|---|
| Overview/Recommendation 18 Program | Mr. Neal Blake |
| Cockpit Human Factors/ Recommendation 10 Program | Mr. Harry Verstynen |
| Fuel Conservative Profiles | Mr. Harry Verstynen |
| Automated IFR | Mr. Michael Perie |

The charts used in these presentations are shown in Appendices F through I.

Discussion:

Mr. Poritzky reiterated that NASA personnel connected with the TCV program and Panel members should analyze the FAA programs to see if the TCV program can help in any of these areas. He requested that FAA comment on this possibility.

Mr. Hodge stated that since some of the FAA representatives were not fully aware of the features of the TCV program, they probably were not prepared to make any such comments. However, any comments would be welcomed.

Mr. Poritzky stated that the whole object of the FAA presentations is to see if the TCV program can ease implementation of FAA programs.

Mr. Litchford stated that he was not in agreement with some of the overall philosophy of the FAA programs. He felt that the military aircraft had not been given adequate consideration. Many military aircraft use Mode C. He feels that the TCV program and the DABS program should be tied together more closely.

In relation to the RNAV program, Mr. Poritzky observed that in his opinion the program is validating again many of the things that are already known. He stated that defining flight technical errors involves large amount of statistical data. Data gathered by just one aircraft probably would not be believed. Mr. Rich responded that large amounts of data are available but people would not accept the results. So he is trying to gather more data which would be believable. Mr. Litchford stated that RNAV and vectoring must be tied together to overcome the shortcomings of both.

Relative to the Wake Vortex Avoidance System and Wind Shear programs, Mr. Litchford expressed concern that measurements are being made in ground effect yet there is a safety problem also further back in the approach path. Captain DeCelles stated that the program should look at the hazards to a landing aircraft following an aircraft which had executed a missed approach. Mr. Blake stated that measurements of situations which Captain DeCelles had described will be taken.

Following Mr. Verstynen's presentation on Cockpit Human Factors, Mr. Gorham observed that it would not be sensible to put cost-effective figures on safety. Mr. Poritzky observed that when the benefits of a program are increased safety, cost-effective studies usually result in a lot of wasted effort. Mr. Verstynen felt that the TCV program can be useful in the Cockpit Human Factors program. He emphasized that this FAA program is not yet an approved program but is being formulated at the direction of DOT (Recommendation #10).

In regards to Phase III (Program for Future Aircraft) of the Cockpit Human Factors program, Mr. Gorham stated that industry designs cockpits and makes them safe, FAA Flight Standards Service certifies that the design is safe, and that FAR's are not written from research results. Mr. Patten felt that FAA is not responding to the intent of the DOT Committee which made Recommendation #10. He suggested that FAA present the plan to the Committee to see if in fact FAA is responding to the Committee's recommendation. Mr. Blake stated that Committee had been disbanded; however, the FAA plan will be reviewed by the FAA Executive Committee before approval.

Mr. Stahr inquired if the Automated IFR Traffic Control concept can be implemented with existing aircraft instrumentation or will the aircraft and pilot need additional equipment? Mr. Perie responded that this is still an open question.

Performance Improvements in Operating Systems which TCV Program Technology is Projected to Achieved:

A recommendation of the last Panel meeting was "clearly delineate present system capabilities and show the performance improvement that the TCV program is projected to achieve". Mr. Reeder used the charts shown in Appendix J to show the expected benefits and quantitative targets, where practical, of TCV program technology output.

Discussion:

Mr. Andersen stated that he would like more specifics on the TCV program research activities, what are the deliverables, and what is the schedule. Mr. Reeder stated that details of TCV tasks to be conducted during the next year will be presented later on the Panel agenda.

Mr. Litchford recommended that NASA personnel review the FAA Advisory Circular on Navigation Accuracy, AC 90-45. He doubts that some of the targets stated by Mr. Reeder can be achieved technically.

Mr. Poritzky stated that TCV goals are compatible with figures stated by FAA. He feels that a useful output of the TCV program would be to show whether the FAA goals can or cannot be achieved or that such things like DABS are not required in order to achieve the goals.

Mr. Reeder used the charts shown in Appendix K to show a comparison of NASA's B-737 RNAV capability versus a typical current generation RNAV system.

## Results of Studies of Independent Landing Monitor Sensors:

Mr. W. T. Bundick, Radar Systems Section, Flight Instrumentation Division, Langley Research Center, used the charts shown in Appendix L to summarize the results of a NASA sponsored analytical study by Honeywell Inc. of ILM sensors. No tests were conducted nor were human factors or displays considered.

## Discussion:

Mr. Andersen asked the difference between this study and an FAA/Boeing study. Mr. Stitt responded that this NASA sponsored study was conducted as a result of a recommendation by the parent RTAC panel for "the quantitative determination of the weather-penetrating potential of airborne sensor systems technologies (such as IR and lasers)".

Mr. Poritzky asked Mr. Bundick to define ILM. Mr. Bundick stated for the purposes of this study, ILM sensors were defined as shown on his second vugraph.

Captain DeCelles said that the only times he has experienced a need for these types of sensors were for taxiing for which there is a need for a wider angle coverage than shown on the charts. Mr. Bundick stated that he had not foreseen this requirement.

Mr. Poritzky questioned the merit of the computer programs used in the analysis in view of the results obtained for low light level TV. Mr. Stitt stated that the ranges shown were computed using the attenuation at these wavelength by atmospheric water vapor which varied according to the amount of water vapor present for each of the RVR's examined. The results show that LLTV is probably not the answer for a weather penetrating sensor.

Mr. Litchford asked if leader cables were considered. Mr. Bundick responded in the negative.

Mr. Stitt asked the Panel for a recommendation on whether or not NASA should continue investigations in this area, especially on imaging systems? Mr. Poritzky said that hopefully NASA should take up where this study stopped. Any system should provide a real world image that could be observable and interpreted at a glance. NASA should address the question of whether a sensor such as FLIR might with additional research provide a useful pay-off. The documentation of past research results is not what is needed; rather NASA's research should take-off from there.

Captain DeCelles stated that there is a need for a sensor which penetrates fog. He doesn't think that FLIR will do this. Mr. Poritzky stated that he had seen the results of some new developments in FLIR which show some promise of it being useful in fog. Captain DeCelles recommended that NASA look into weather radar for use in taxiing in very poor visibility.

NASA's Response to Previous Panel Recommendations

Mr. James E. Stitt, Director for Electronics, Langley Research Center, using the charts shown in Appendix M, discussed what action NASA had taken relative to these recommendations.

In regards to strengthening coordination with FAA, Mr. Stitt stated that the briefing at this panel meeting and previous briefings to Langley personnel (approximately annually) by the Office of Systems Engineering Management, FAA, were very beneficial and were needed by Langley personnel. Coordination must be continued. Frequent planning meetings on TCV activities have been held.

The objectives of the TCV program are being reworked and have received the benefit of comments and recommendations at this session.

There has been no NASA activity during the past year and a half on weather penetrating sensors following the NASA sponsored study by Honeywell. He requested that the Panel formulate a recommendation on future NASA activities in this area.

High level planning meetings have been held recently between the Directors of LaRC and ARC to define activities over and above their research and technology base programs in the human factors area. Ames Research Center has the lead center role in these activities and will be responsive to TCV human factors elements.

With reference to defining present system capabilities and improvements that the TCV program is projected to achieve, Mr. Stitt felt that this subject needs more discussion by the panel.

In regards to having an additional FAA member on the panel, this will be discussed later in the meeting.

## Results of Ames/Langley Conferences on Human Factors

Mr. Alan B. Chambers, Chief of Man-Vehicle Research Division, Ames Research Center, stated that ARC had informed Langley personnel of on-going programs which might be applicable to TCV human factors needs. He provided a compilation of reports and papers which are products of the Ames human factors program basic research studies. This compilation is attached to these minutes as Appendix N. Ames has received from Langley a listing of areas of suggested Ames support for TCV. This list includes:

- HUD - role and limitations
- Computer address requirements and techniques
- Decision-making process and assessment during man/environment/machine interaction
- Field of view of displays
- Requirements for motion cues for displays

Discussion:

Mr. Stitt stated that the above list has been sent to ARC asking them to undertake these activities. Ames will respond with scope and schedule of the research. Funding has not been addressed yet.

Mr. Gorham said that he is very pleased with this activity. It should be beneficial to both Centers. It is a step in the right direction. The Panel will comment when the program is defined in detail.

Results of MLS Demonstrations to the All-Weather Operations Panel, ICAO:

Dr. Thomas M. Walsh, Radar Systems Section, Flight Instrumentation Division, Langley Research Center, using the charts shown in Appendix O, described the TCV B-737 configuration and performance during demonstrations of TRSB MLS to the AWOP members and technical staff at NAFEC on May 12-14. Dr. Walsh showed video tapes of the autolandings under wind shear conditions and strong crosswinds.

Discussion:

Dr. Walsh stated that since the ICAO demonstrations, true autoland flights have been conducted using body mounted accelerometers, and the results have been substantially the same.

Mr. Poritzky was of the opinion that additional work on autoland using an air data filter technique that obviates the need for accelerometer data would not be worthwhile. Mr. Goolsby stated that this work was being done at the specific request of the FAA and also in response to a previous recommendation of this panel "to examine the minimum airborne system elements for MLS approach and landings and which seeks maximum advantage of the MLS signal quality". Mr. Greer said that this technique would reduce the complexity of the airborne system.

Mr. Hersh asked if EL-2 is an operational requirement for MLS. Mr. Poritzky responded that it is not yet a requirement. He feels that we shall never see EL-2 implemented practically.

In automatic 3-D flight, the volumetric signal coverage of the TRSB MLS can be exploited with precision to perform complex curved paths with short turns into final approach and through landing and rollout.

Improved Approach and Landing Monitoring Displays:

Mr. Samuel A. Morello, Flight Programs Branch, Flight Research Division, Langley Research Center, described work underway aimed at improving displays for pilot monitoring during autoland. He described progress which has been made since the last Panel meeting. Some modifications have been made to the displays in the TCV B-737 since the ICAO demonstrations. Two flight experiments have been conducted at NAFEC using the thinned array MLS. He explained the Star and Circle Symbology using charts shown in Appendix P.

Discussion:

Captain DeCelles felt that there were too many sources of the same information on the display. Mr. Morello stated that if he is referring to the localizer signal, it would be used for far out, say five miles, while the runway symbology would be for close-in work.

Captain DeCelles stated that air carrier pilots will not land on head-down displays and flight directors. The policy is to use autoland for touchdown. The pilots want HUD and raw data display. The scaling of displays need more investigation on how much can you shrink a display and still get a real world feeling. He requested that his views on the most important questions that the TCV program needs to resolve be appended to these minutes. They are contained in Appendix Q.

Mr. Hersh stated that American Airlines has made a study that shows that conventional displays can be used for curved, complex approaches down to low altitudes.

Mr. Gorham expressed the view that it is the position of commercial airlines that displays will never be used for actual landings. It is the feeling of industry that displays will not be used for curved and complex approaches in very low visibility.

Mr. Stahr stated that he disagreed with Mr. Gorham on two points. The type of display discussed can be developed to a point where it will be used for curvilinear approaches. He can't support the statement that head down displays will never be developed which are good enough for touchdown.

Mr. Patten cautioned that the TCV program should not get hung up on having an aft cockpit and having to use it. He agreed that the TCV B737 should be flown in the MLS environment, but don't get hung up with display symbology because of the aft cockpit. He observed that Ames has been asked to work on HUD while Langley is now working the head down display. Mr. Stitt said that this will provide technology options on which to base logical decisions. Mr. Patten restated his caution that he feels that Langley is getting hung up on display symbology.

Mr. Poritzky stated that there will be electronic displays in aircraft, and this work is aimed at seeing how you can use them. Sam Morello's work is entirely separate from MLS. Air carriers are going autoland but not beyond CAT IIIA. He feels enthusiastic about this work. It is a weeding process. He stated that the ICAO demonstration was good work in a short time, and many people commented on the benefits of it.

Captain Henderson stated that we have to have some weeding out process in R&D.

Mr. Gorham stated that the use of flight directors for landing had been weeded out long ago by others. He agreed with Mr. Stahr and Mr. Poritzky on the need to do work on electronic displays. The real need is to find out the best way to let the pilot know what the autoland system is doing.

Mr. Poritzky said that there are many schools of thought on how to monitor what is going on. The activities just explained by Mr. Morello is examining one method.

Mr. Andersen again stated that he would like for NASA to define the deliverable products from this research.

Mr. Creer said that this is often a difficult problem. He has asked industry on several occasions how they like the results of technology to be presented. How should information be categorized and cataloged? There is a need from industry to define what are desirable deliverable products.

Mr. Gorham agreed with Mr. Creer. He stated that he and ARC personnel have thought a lot about this problem and haven't come up with an answer. Trends are important, not design handbooks. The format of the data which industry might need and use has not been defined well.

Mr. Stahr felt that some good points have been made. NASA has to have some industry help on how data can be made available for call up. NASA reports are not the whole answer.

Mr. Poritzky pointed out that there are two kinds of data from technology efforts. For example, given that a short final approach will buy some advantages, it is not too difficult to document how you can do it. Human factors areas are different and require different reporting of the data that is gathered and analyzed.

Mr. Patten asked if NASA has read an Army report on Pathway-in-the-Sky (15 years ago). The methodology of that report may be helpful. He stated that he had not seen a single report of any kind as an output of the TCV program. Mr. Stitt asked Mr. Reeder to make out another bibliography of reports and a package of reports and send to each member. (Executive Secretary's NOTE: Appendix III of the minutes of the meeting of the Ad Hoc Panel on TCV, September 10-11, 1975, contained a bibliography of Langley reports relating to TCV program activities)

Airline Crew Scan, Performance Measures and Workload Study:

Mr. Amos A. Spady, Simulation and Human Factors Branch, Flight Dynamics and Control Division, Langley Research Center, used the charts shown in Appendix R to describe progress since the last meeting on the use of the oculometer in measuring pilot instrument scan patterns and the results of a NASA sponsored Honeywell workload study.

Discussion:

Mr. Spady estimated that the oculometer will be used in Sam Morello's display simulations in September. The equipment cannot go in an aircraft now because of its bulk. However, a model should be available for aircraft use around the first of the year. He stated that a dim red light is the only indication to the pilot of the presence of the oculometer. The pilot is free to move his head within a volume of one cubic foot.

Following a film clip of a pilot scan during the simulations at Piedmont Airlines, Captain DeCelles observed that the film clip really illustrates what is wrong with present instrument panels. He also commented that when the simulations recommence at Piedmont with an improved oculometer after the first of the year, it is important to study during the transition period when the pilot looks out of the cockpit then looks back in, what does the pilot look at.

Mr. Gorham stated that the oculometer and timeline analysis work impresses him. This is the first truly scientific approach to the problem. He hopes that the results of this work can be used to design a better cockpit. Hopefully the output would be techniques to better cockpit design and a timeline for measurement of how good it is.

Mr. Creer inquired on how the data from these efforts is going to be used to design better cockpits. Mr. Spady replied that one use is in modelling. He explained that this program is new and he is not sure of the total use. Mr. Stitt said that these tools can be used to look at new display concepts. It will be a prime tool in looking at display concepts. Mr. Hersh observed that besides being a design tool, the oculometer can be useful in training.

Mr. Patten stated that the work just described is an example of work which will be useful to industry. It should be especially useful in taking personal opinion out of the HUD versus head down display arguments.

Mr. Stahr said this program could provide valuable human factors information. For example, crew members could be asked what they think they do and then they could be shown what they actually do.

The Panel expressed strong interest in an endorsement of this program. Accordingly, the Panel drafted and unanimously endorsed the following Resolution:

Resolution on the Use of Oculometer as a Research Tool

It is resolved that:

The RTAC, Ad Hoc Panel on Terminal Configured Vehicles believes that the oculometer work being done is well organized and managed. It has considerable potential in developing new cockpit display arrangements including display concepts, and for flight training improvement.

Since electronic displays are capable of displaying an infinite variety and arrangement of data, this effort should also be useful in practically enhancing the value of electronic displays.

The Panel also commented that there are significant learning opportunities in the human factors area from the use of questionnaire/interview sessions with airline pilot subjects, both before and after the pilot conducts simulated approaches, and again after the pilot is permitted to view the results of his actual scan pattern.

TCV Program Activities in Fy 1977:

Mr. James Hall, TCV Program Office, Langley Research Center, summarized TCV related research tasks which will be active during the next six months and from which some results may be expected before the next Panel meeting. The work falls into three areas or categories: MLS automatic control, aircraft systems, and crew systems. MLS automatic control encompasses close-in final (less than 1½ miles), new control laws for the MLS environment, reduced sensor complexity and MLS volumetric coverage evaluation. Aircraft systems includes improved handling qualities, sidearm controller analysis and simulation, direct lift control study and simulation, and performance evaluation system development. Traffic situation displays, approach path displays, landing monitor, and human factors investigations will be active under crew systems integration.

Discussion:

Mr. Poritzky wanted to know the point of the work on reduced MLS sensor complexity and MLS volumetric coverage evaluation. He stated that Ames had done a lot of work on MLS volumetric coverage requirement. Mr. Stitt explained that the reduced MLS sensor complexity involves investigating, as recommended at the last Panel meeting, the minimum airborne system elements for MLS approach and landings and which seeks maximum advantage of the MLS signal quality. This does not imply any changes in the ground system. He stated that the FAA had specifically requested a flight demonstration of the use of an air data filter technique that obviates the need for accelerometer data. Langley personnel will discuss with FAA the need for any additional data on MLS volumetric coverage. If none, this activity will be dropped.

Mr. Poritzky asked what will be the output in the other three areas under MLS automatic control development. Mr. Reeder stated that new flare laws and autopilot improvements are needed in order to be able to do other research tasks.

Mr. Gorham opined that CTOL flare law work in advance of what is being used in the TCV 737 aircraft is already available. He observed that a lot of the activities described by Langley appear to be needed to make the TCV 737 a better tool to do its technology work later. It is not at this time aiding directly technology advancement.

Mr. Creer asked for an explanation of the item "TCV 737 Handling Qualities". Mr. Reeder responded that this effort would provide a baseline documentation of the modified 737 handling qualities. Mr. Hersh stated that he couldn't understand this work on the B-737 since the B-737 handling qualities are well known, and it has very satisfactory handling qualities.

Mr. Stahr observed that a lot of these discussions showed that many had lost sight of the basic premise of the TCV 737. It has been extensively modified to make it a better tool in simulating future aircraft in a future ATC environment. The work at Langley is not directed at improving the B-737's now in the current fleet of air transport aircraft. Captain Henderson stated that he hopes that Langley personnel are aware of the work that Lockheed and Douglas have done in direct lift control. Mr. Gorham stated that direct lift control technology was already in hand and was well documented. Mr. Goolsby responded that the TCV task was not concerned with the design of direct lift control systems but rather to see how direct lift control systems could ease the pilot workload in complex approach paths under MLS guidance. The work was supported by the Panel during its previous meeting.

Mr. Poritzky pointed out that what is apparently causing some confusion to the assembled group is that the TCV tasks have been given ambiguous titles. He stated that this could be avoided if the tasks were more precisely labeled.

Mr. Andersen inquired about the amount of manpower being applied to the aircraft systems area. Mr. Taylor responded that three in-house and one contractor man-year were being expended on the whole aircraft system package.

Mr. Gorham stated that these discussions had revealed that during the next six months, TCV program activities will consist of:

- putting deficiencies right in the TCV 737.
- getting the aircraft ready for technology experiments.
- improving the capabilities of the TCV 737 to give it increased capabilities for simulation of advanced aircraft in a future ATC environment.

Mr. Poritzky stated that it seems that this is work which needs to be done.

Request For Panel Recommendations:

Mr. Reeder asked for Panel recommendations for NASA action with regard to weather penetrating sensors and a NASA program in helping to define the pilots' role in a future ATC system.

Discussion:

Captain DeCelles stated that no one is interested in turning over to the pilot what the controller does on the ground. However, the pilot should provide some redundancy in the system. He should have data in the cockpit in order that he can check that the controller is doing the right thing. Mr. Howell stated that ALPA is concerned about all elements of the ATC system. The pilot seems to be designed out of the information cycle. ALPA is very much interested in the pilot's role. He feels that using an electronic display in the TCV aircraft is a good means of investigating the problem to see what the pilot can contribute to the ATC process.

Mr. Andersen recommended that an experiment be conducted in the TCV program wherein beacon data is uplinked to a cockpit display to see what the pilot can do with this information. Dr. Walsh said that by February 1977, the ground-to-air data link at Wallops Flight Center will be completed. Working closely with FAA, Langley will then continue the work started at MIT in this area. Mr. Reeder stated that a trend vector which represents the predicted future aircraft position will be included on the traffic situation display.

Mr. Hersh endorsed the task of trying to define the pilot role in the ATC process. He feels that the pilot will definitely have some expanded roles. Boeing has been looking into this problem and has lots of data.

Mr. Stitt stated that perhaps NASA should propose a strawman program and then discuss it with FAA. One question appears to be how far NASA should go in this area.

Mr. Poritzky stated that the role of the pilot in an automated ATC system needs investigation. However, the FAA has not yet defined an automatic ATC system. He cautioned that NASA should not redo what MIT and others have already done. The area which should be investigated is to what degree can a pilot assimilate ATC information and act on it in a busy terminal area. He suggested that NASA not build equipment but to study and analyze. Work closely with FAA to get an indication of what could be done.

Mr. Stahr said that he had been trying to get management of Eastern Air Lines interested in flight experiments of this nature. He feels that NASA's human factors personnel should work with airline pilots in real ATC environments. For example, a captain can help the controller predict the time he will be over fixes and make changes if the controller desires it.

Mr. Poritzky feels that NASA should not get involved in the areas of distributed/strategic ATC concepts. If the U.S. should ever have an automatic ATC system, the role of the pilot needs definition. He feels this is not within NASA's role to investigate. Mr. Gorham feels that maybe some parts of it could properly be. Mr. Poritzky responded that the interface between the pilot and controller is a crucial one and should be well defined. There cannot be two people in charge at the same time. FAA should first define automatic ATC.

Mr. Creer didn't agree with this approach. He feels that it may be better to work the pilot's role and automatic ATC together.

Mr. Erwin raised the question of the meaning of getting the pilot involved in the ATC process. He asked if looking out of the cockpit window and questioning conflicting aircraft is getting involved in ATC. It certainly is safety related but not real ATC involvement.

Relative to weather penetrating sensors, Mr. Poritzky recommended that NASA conduct a scientific investigation of weather penetrating sensors. This should not replow old ground on old sensors and result in a summary of past work. He feels that there has been some recent real progress in IR sensor systems.

Mr. Gorham summarized the discussions by stating that the Panel would not like to give NASA any specific recommendations at this time. The Panel would prefer to present at a later time well thought out recommendations which have been agreed to by a majority of Panel members.

Mr. Poritzky recommended again that FAA have two representatives on the Panel. One should be from Flight Standards Service and one from the Office of Systems Engineering Management.

The meeting was adjourned at 2:40 p.m., July 22, 1976.

Submitted:

Lee D. Goolsby

Lee D. Goolsby
Recording Secretary

Concur:

Kenneth E. Hodge

Kenneth E. Hodge
Executive Secretary

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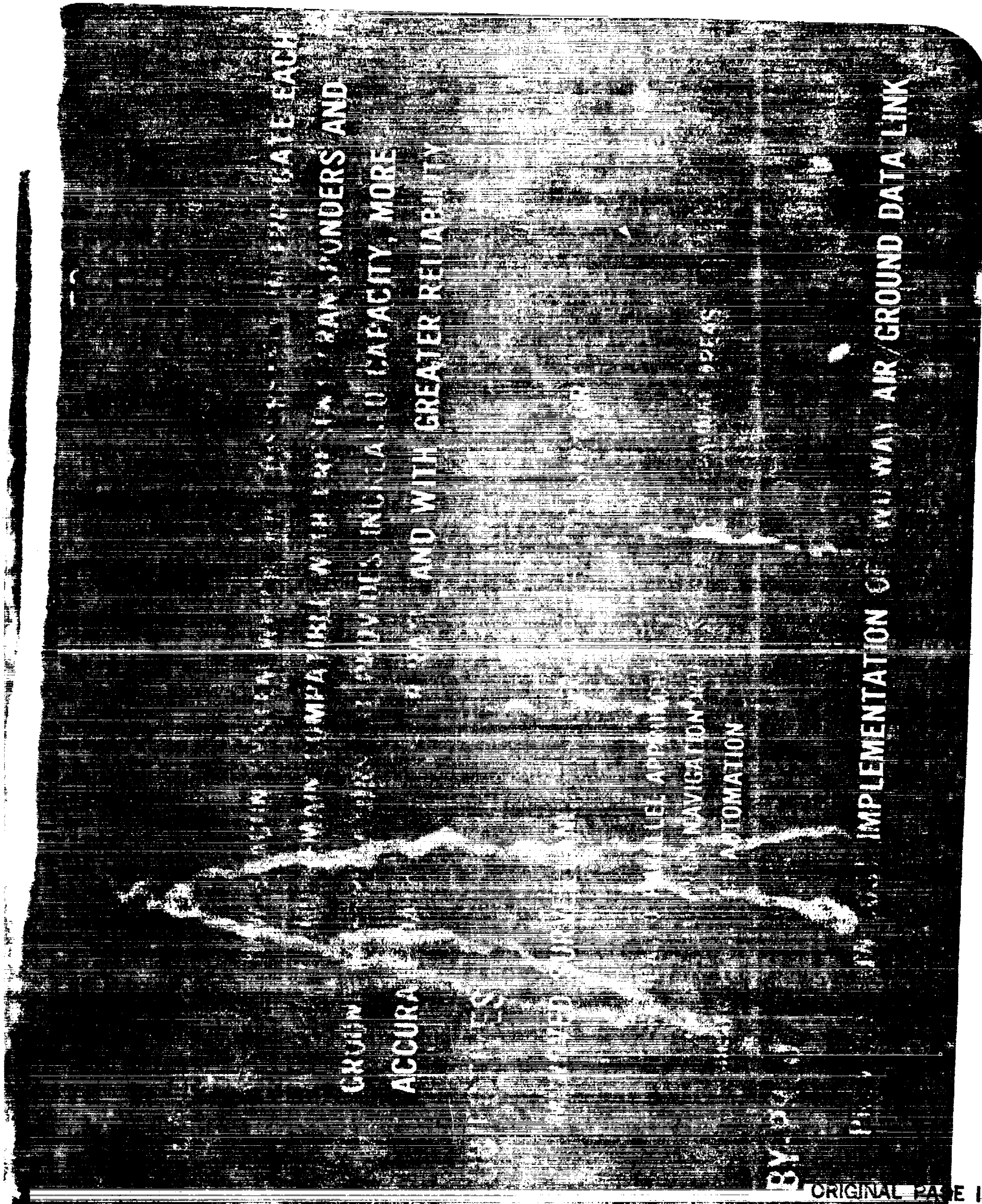
APPENDIX A

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DABS FEATURES

## DABS SURVEILLANCE

- UNIQUE ADDRESS
- RANGE-ORDERED ROLL-CALL INTERROGATION
- MONOPULSE DIRECTION FINDING
- ADAPTIVE REINTERROGATION
- SURVEILLANCE MANAGEMENT

## DABS DATA LINK

- GROUND TO AIR
- AIR TO GROUND
- ERROR PROTECTION

## ATCRBS SURVEILLANCE

- REDUCED PRF
- MONOPULSE DIRECTION FINDING
- IMPROVED DEGARBLING
- FALSE TARGET IDENTIFICATION

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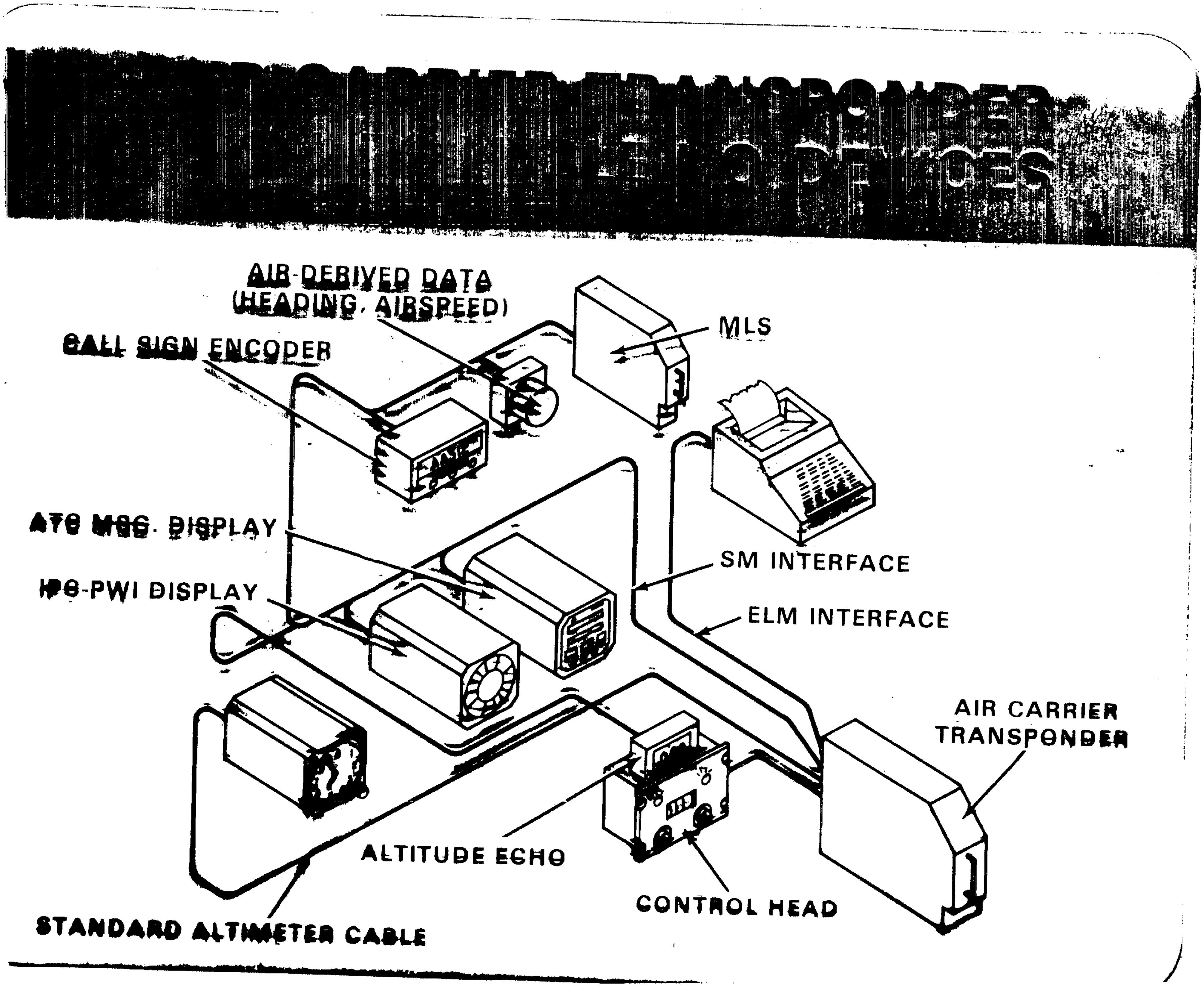
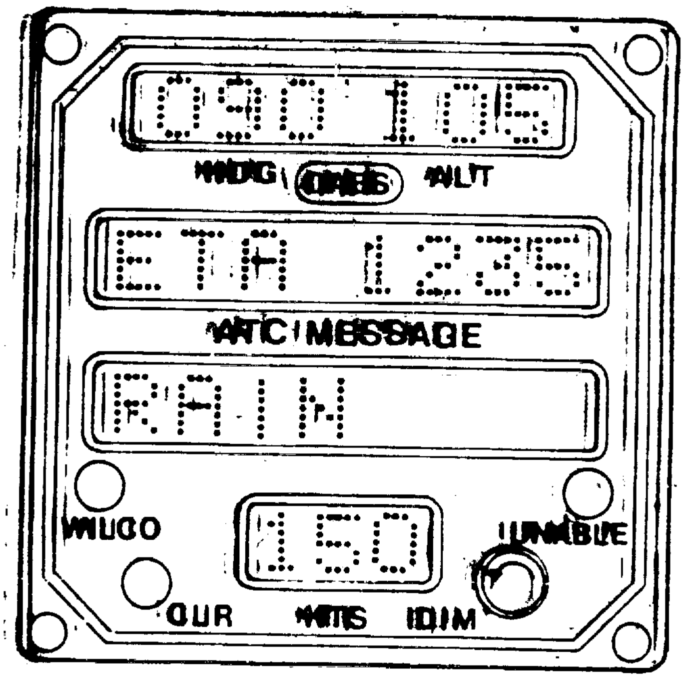

AIR-DERIVED DATA
(HEADING, AIRSPEED)
CALL SIGN ENCODER
MLS
ATC MSG. DISPLAY
IPS-PWI DISPLAY
SM INTERFACE
ELM INTERFACE
AIR CARRIER
TRANSPONDER
ALTITUDE ECHO
CONTROL HEAD
STANDARD ALTIMETER CABLE




CANDIDATE ATC MESSAGE DISPLAY

## DABS EQUIPMENT ON ORDER

| | |
|---|---|
| 3 | SENSORS |
| 20 | GENERAL-AVIATION-TYPE DABS TRANSPONDERS |
| 10 | AIR-CARRIER-TYPE DABS TRANSPONDERS |
| 30 | IPC/PWI DISPLAYS |
| 10 | ATC MESSAGE DISPLAYS |

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## DABS SCHEDULE

| | |
|---|---|
| • SENSOR DEVELOPMENT CONTRACT AWARDED (TEXAS INSTRUMENTS, INC.) | 2/76 |
| • NATIONAL STANDARD FOR DABS AVIONICS | |
| = RTCA COORDINATION DRAFT | 7/76 |
| = FINAL | 1/78 |
| • TERMINAL SENSOR TESTS BEGIN AT NAFEC | 2/78 |
| • EN ROUTE SENSOR TESTS BEGIN AT ELWOOD, NEW JERSEY | 5/78 |
| • PHILADELPHIA SENSOR TESTS BEGIN | 8/78 |
| • FIRST TRANSPONDERS AND COCKPIT DISPLAYS AVAILABLE | 8/78 |
| • BEGIN MULTI-SENSOR NETWORK TESTING | 8/78 |
| • BEGIN OPERATIONAL FIELD TRIALS AT PHILADELPHIA | 8/78 |
| • FINAL TECHNICAL DATA PACKAGE (SPECIFICATION) FOR MULTIPLE SENSOR DABS/IPC | 7/79 |
| | 1/80 |

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APPENDIX B

## CONTROL MESSAGE AUTOMATION

- CAPABILITY FOR AUTOMATIC SELECTION, IDENTIFICATION, AND PROCESSING OF CONTROL AND SERVICE INFORMATION TO BE TRANSMITTED TO AND RECEIVED FROM AIRCRAFT VIA AUTOMATED DATA DELIVERY SYSTEM.

- INTERFACES WITH
  - A/G DATA LINK OR VRS
  - CONTROLLER VIA PVD AND KEYBOARD
  - VARIOUS AUTOMATION ENHANCEMENTS

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## TYPES OF MESSAGES CONSIDERED

- CONTROL
  - HEADING, ACTITUDE AND SPEED COMMANDS
  - RADIO FREQUENCY ASSIGNMENTS
  - ROUTE CLEARANCES
  - HOLD AND RELEASE DATA
  - GROUND GUIDANCE
  - BEACON CODE ASSIGNMENTS
- ADVISORY
  - SAFETY ADVISORIES
  - WEATHER INFORMATION
  - ATIS AND NOTAM INFORMATION

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## PRESENT STATUS

**TERMINAL**

- INITIAL CONTROLLER-COMPUTER INTERFACE TESTS IN DSF COMPLETED (REPORT FAA-RD-75-133, I AND II, 9/75)
  - SKELETON METERING AND SPACING SCENARIO
  - MIXED AIRCRAFT ENVIRONMENT
  - MIXED CONTROL SCHEME
- CONTROLLER-COMPUTER INTERFACE TESTS IN TATF COMPLETE (REPORT IN FINAL DRAFT)
  - FURTHER REFINED HUMAN FACTORS EVALUATION

**EN ROUTE**

- INITIAL CONTROLLER-COMPUTER INTERFACE TESTS IN SSF COMPLETED (REPORT MTR-7086, 11/75)
  - ROUTINE CONTROL SUPPORT FUNCTIONS

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# CMA PROGRAM SCHEDULE (TENTATIVE)

## TERMINAL

- STUDY PLAN, TAKING INTO ACCOUNT: 1/77
  - IPC
  - CONFLICT ALERT AND RESOLUTION
  - FSS
  - ARTCC
  - M & S
  - AIRCRAFT PERFORMANCE DATA
  - TERRAIN AVOIDANCE
  - WAKE VORTEX
  - FLOW CONTROL
  - AREA NAVIGATION
- SIMULATION DEMONSTRATION 6/78
- T & E COMPLETE 9/78

## EN ROUTE

- PRE-DEPARTURE CLEARANCE 9/77
- EN ROUTE CLEARANCE 10/77
- DEPARTURE/ARRIVAL CLEARANCE 9/78
- DELIVERY SERVICE AND ADMINISTRATIVE 1/79
- FINAL REPORT 3/79

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APPENDIX C

# FAA

# Aircraft Separation Assurance Program



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# Characteristics Of The Problem

- MIDAIR COLLISIONS ARE RARE EVENT—60 FATALITIES ANNUALLY (1960-74) (10 COLLISIONS INVOLVING AIR CARRIERS SINCE 1956; 3 BETWEEN AIR CARRIERS
- ADVENT OF JUMBO JETS RAISES SPECTER OF A CATASTROPHIC ACCIDENT
- MOST (> 80%) ACCIDENTS AND NEAR-MISS REPORTS INVOLVING AIR CARRIERS ARE BETWEEN AIR CARRIER AND GENERAL AVIATION
- GENERAL AVIATION WILL BE THE MAJOR AVIATION GROWTH SEGMENT (153,000 IN 1974 TO 201,000 BY 1985)
- PROTECTION NEEDS:
  - I. AIR CARRIER VS GENERAL AVIATION
  - II. AIR CARRIER VS AIR CARRIER
  - III. GENERAL AVIATION VS GENERAL AVIATION
- SURVEILLANCE MOST IMPORTANT FACTOR CITED BY NTSB IN PREVENTING MIDAIR COLLISIONS

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# GOALS

A. INCREASE MIDAIR COLLISION PROTECTION
TODAY
FUTURE

B. ENHANCE PRIMARY PROTECTION / PROVIDE BACK-UP PROTECTION
1. PUBLIC TRANSPORTATION
2. PRIVATE AND FEDERAL TRANSPORTATION

C. PROVIDE PROTECTION OUTSIDE OF ATC SYSTEM SURVEILLANCE ON AN OPTIONAL BASIS.

D. PLACE PREMIUM ON COMPATIBILITY WITH PRESENT AND FUTURE ATC SYSTEM AND PROCEDURES.

# Aircraft Separation Assurance Program

I CONFLICT ALERT

II NEW SURVEILLANCE AND FLIGHT PLAN REQUIREMENTS

III EXTENDED USE OF TRANSPONDERS AND ALTITUDE ENCODERS

IV BEACON COLLISION AVOIDANCE SYSTEM (BCAS)

V INTERMITTENT POSITIVE CONTROL (IPC)

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# I. Conflict Alert

COMPUTER FUNCTION FOR NAS STAGE A (EN ROUTE) AND ARTS III (TERMINAL).

PROJECTS AIRCRAFT FLIGHT PATHS, SEARCHES FOR CONFLICTS, AND ALERTS CONTROLLER.

CONTROLLER BACK-UP

USES BEACON SYSTEM FOR SURVEILLANCE. REQUIRES MODE C TRANSPONDER AND ALTITUDE ENCODER TO PARTICIPATE IN THE SYSTEM.

STATUS:

| | | |
|---|---|---|
| —ENROUTE: | IMPLEMENTED ABOVE 18,000′ | DEC 75 |
| | IMPLEMENTATION ABOVE 12,500′ | MAR 76 |
| —TERMINAL: | IMPLEMENTATION AT 62 ARTS III LOCATIONS | APR 78 |

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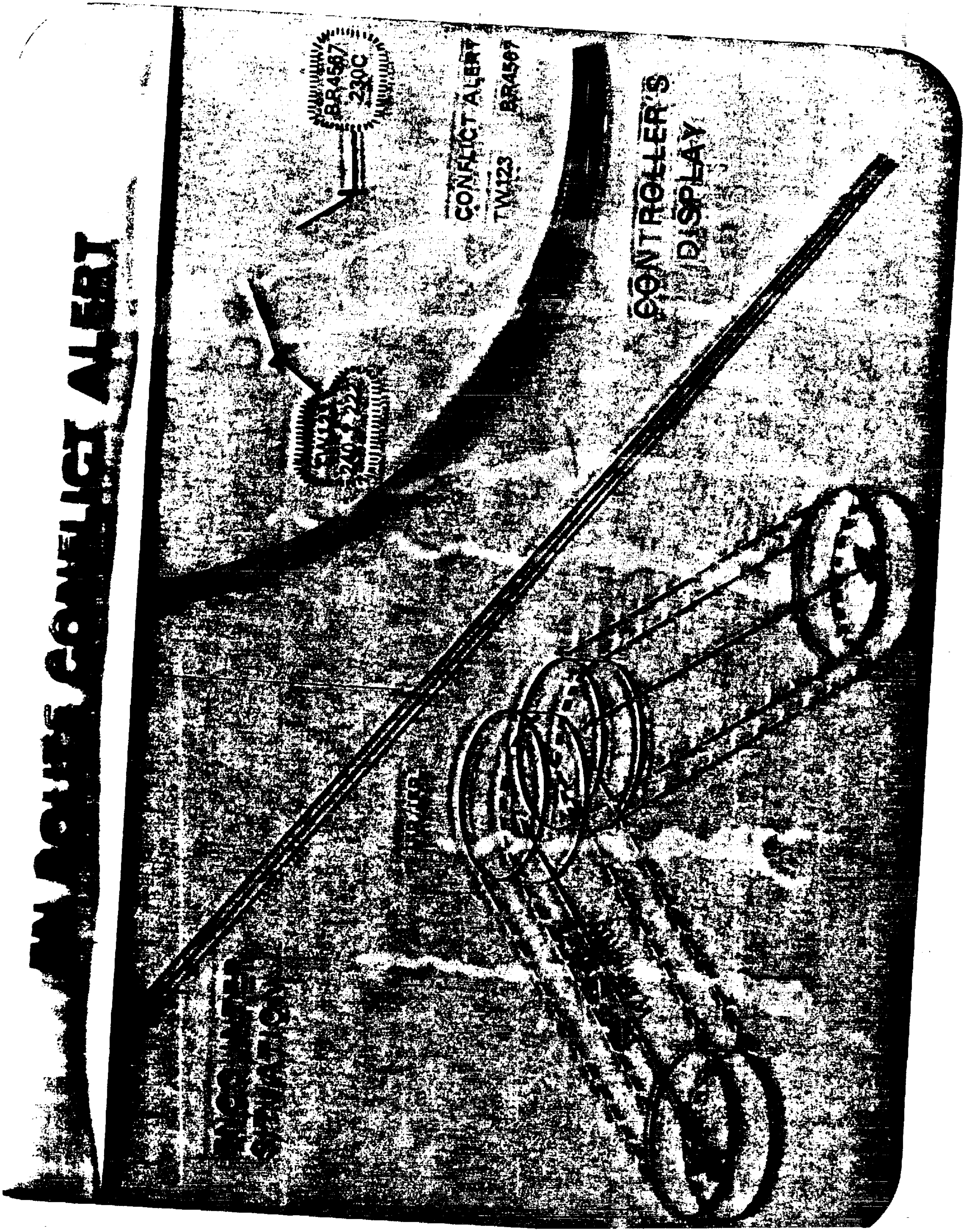

# BCAS

- AIRBORNE COLLISION AVOIDANCE SYSTEM UTILIZING THE ATCRBS (OR DABS) TRANSPONDER AND ENCODER, RESTS ON FOUNDATION OF FULL TRANSPONDER EQUIPAGE.
- PROVIDES BACK-UP TO ATC SYSTEM WITHIN SURVEILLANCE AND NEW PROTECTION OUTSIDE OF SURVEILLANCE INCLUDING OCEANIC AND INTERNATIONAL AREAS (USES ICAO APPROVED TRANSPONDERS).
- BCAS EQUIPPED AIRCRAFT PROTECTED AGAINST OTHER BCAS AIRCRAFT AND ALL AIRCRAFT WITH TRANSPONDERS AND ENCODING ALTIMETERS.
- FIRST AIRCRAFT EQUIPPED HAS IMMEDIATE HIGH LEVEL PROTECTION.
- ONLY THOSE DESIRING ADDITIONAL PROTECTION NEED BUY THE EQUIPMENT.

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## BCAS Systems

- TWO GENERAL TYPES
  - COMBINED PASSIVE/ACTIVE
  - ACTIVE ONLY
- BOTH DABS COMPATIBLE
- OBTAIN ALTITUDE INPUT FROM ENCODING ALTIMETER
- PASSIVE VERSION DESIRABLE FOR USE IN HIGH DENSITY AREAS SINCE PASSIVE MODE (LISTEN-ONLY) DOES NOT CAUSE INTERFERENCE TO GROUND ATC SYSTEM.
- ACTIVE MODE (INTERROGATION) MAY REQUIRE RESTRICTED USE IN HIGHER DENSITY AREAS BECAUSE OF INTERFERENCE TO GROUND ATC.
- BOTH TYPES ARE NOW UNDER DEVELOPMENT BY FAA.

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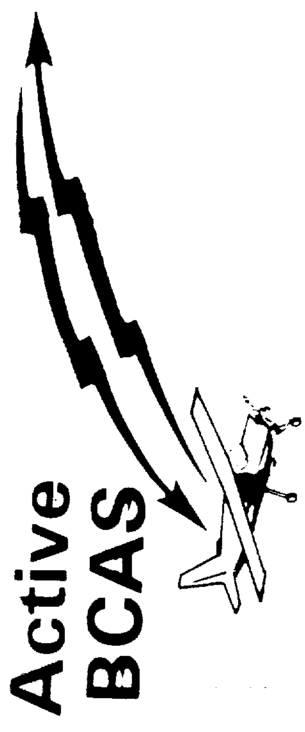
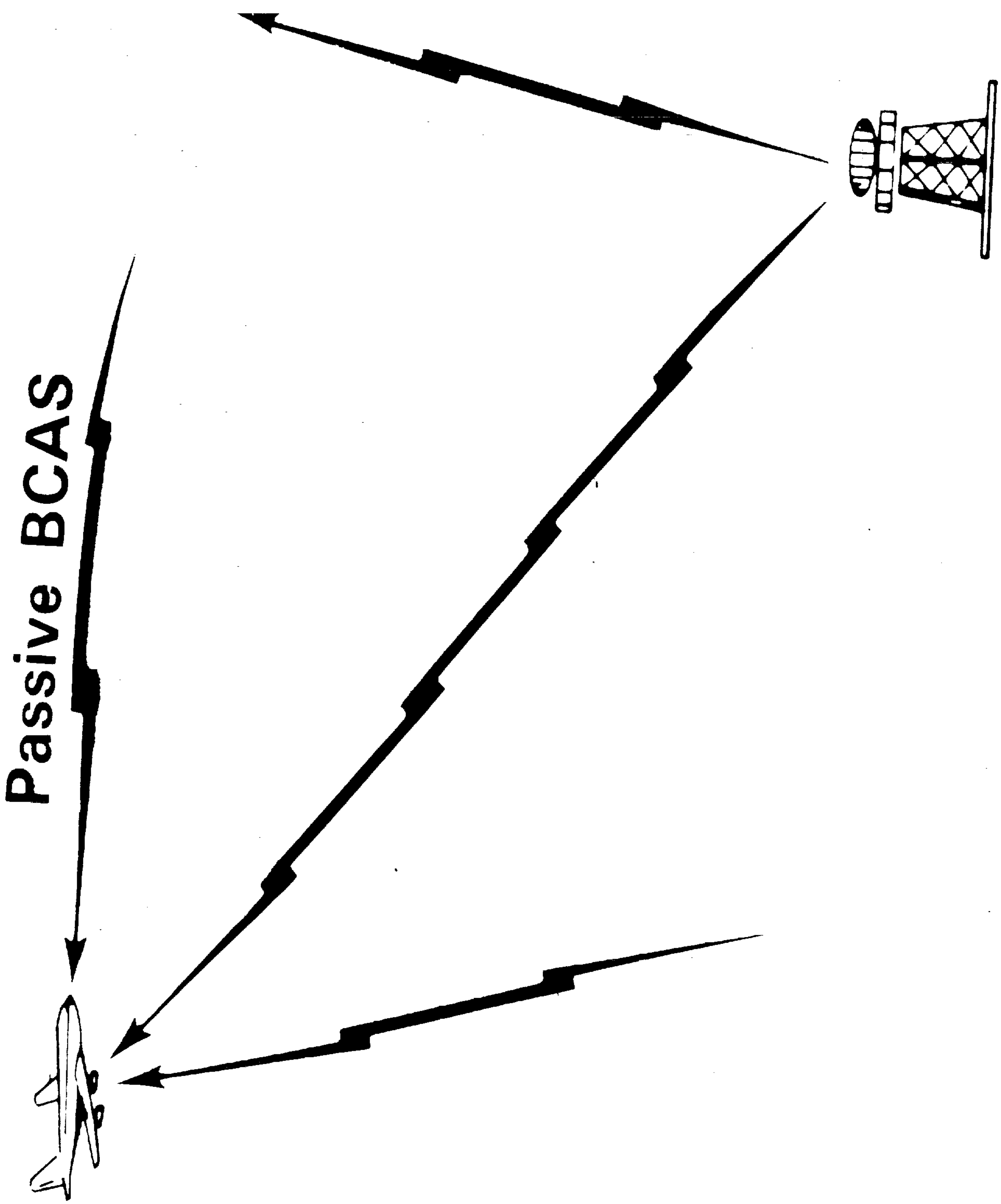
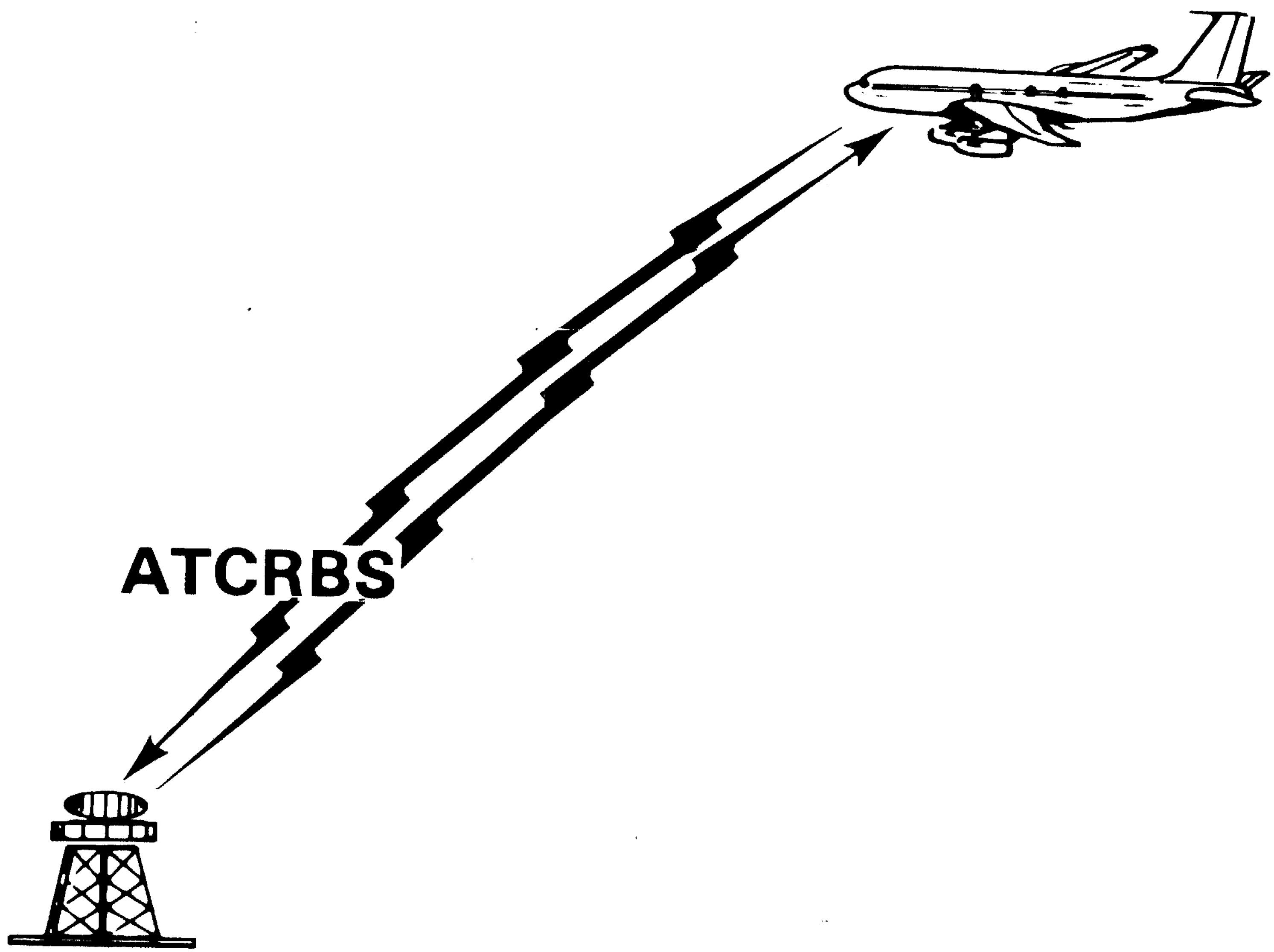
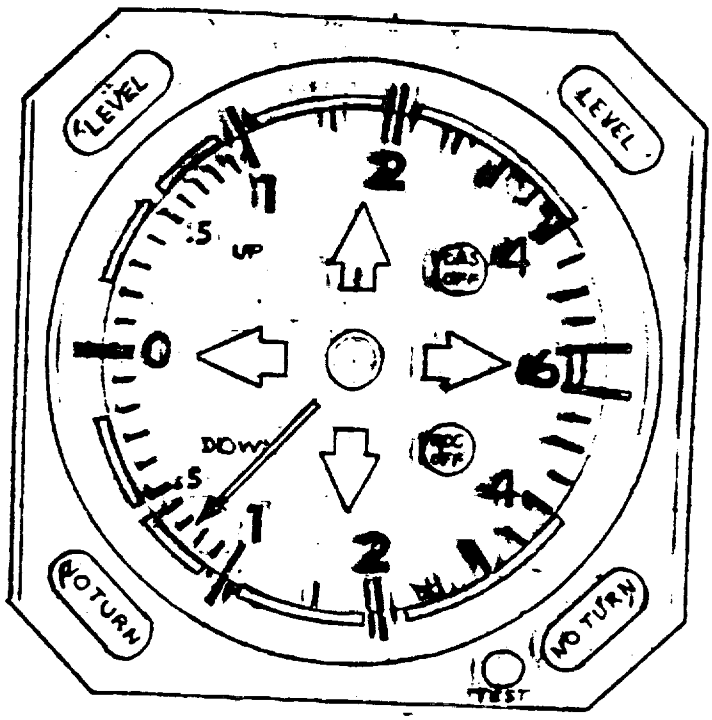

Active
BCAS

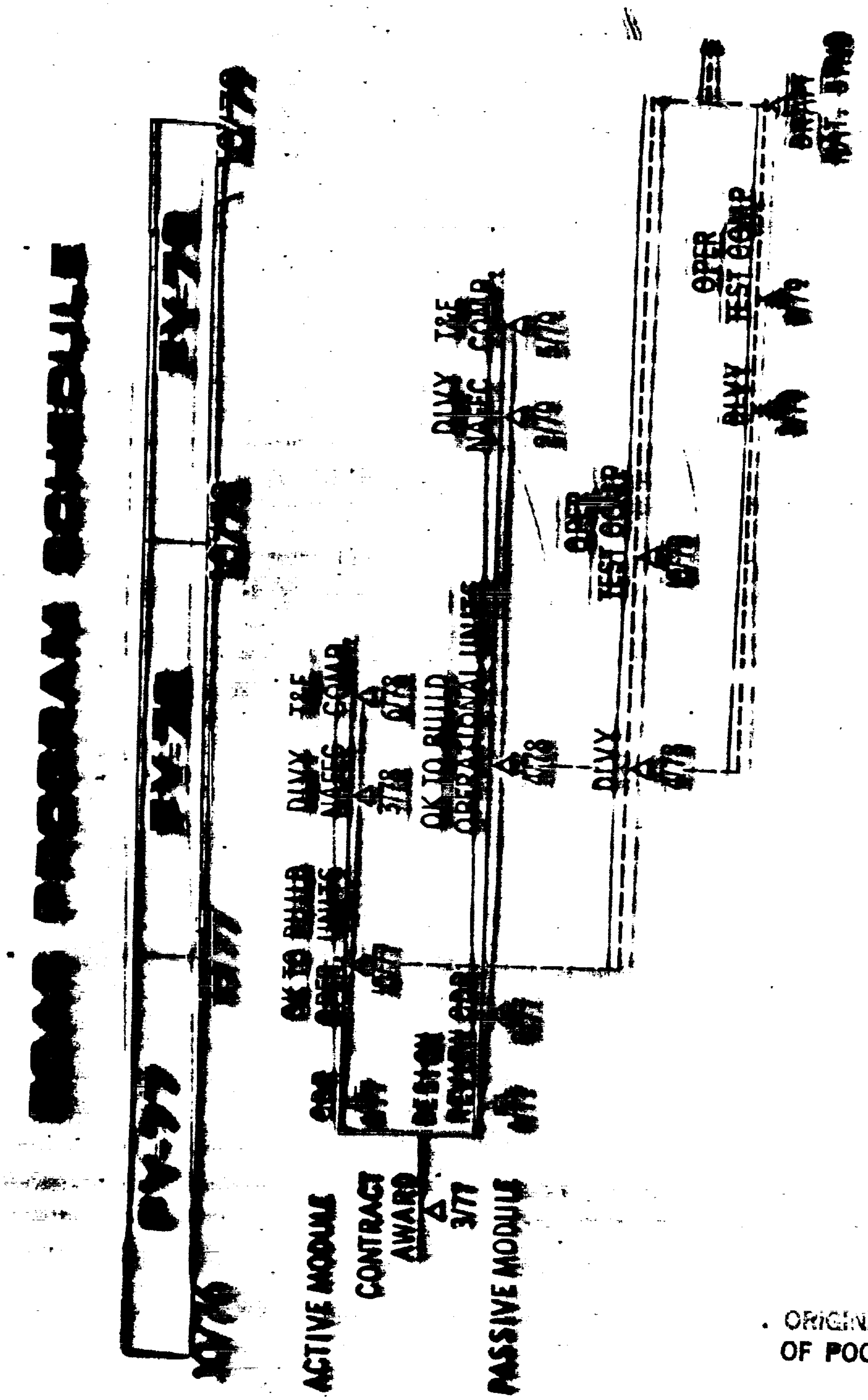

Passive BCAS

# BCAS Concept






CANDIDATE BCAS DISPLAY

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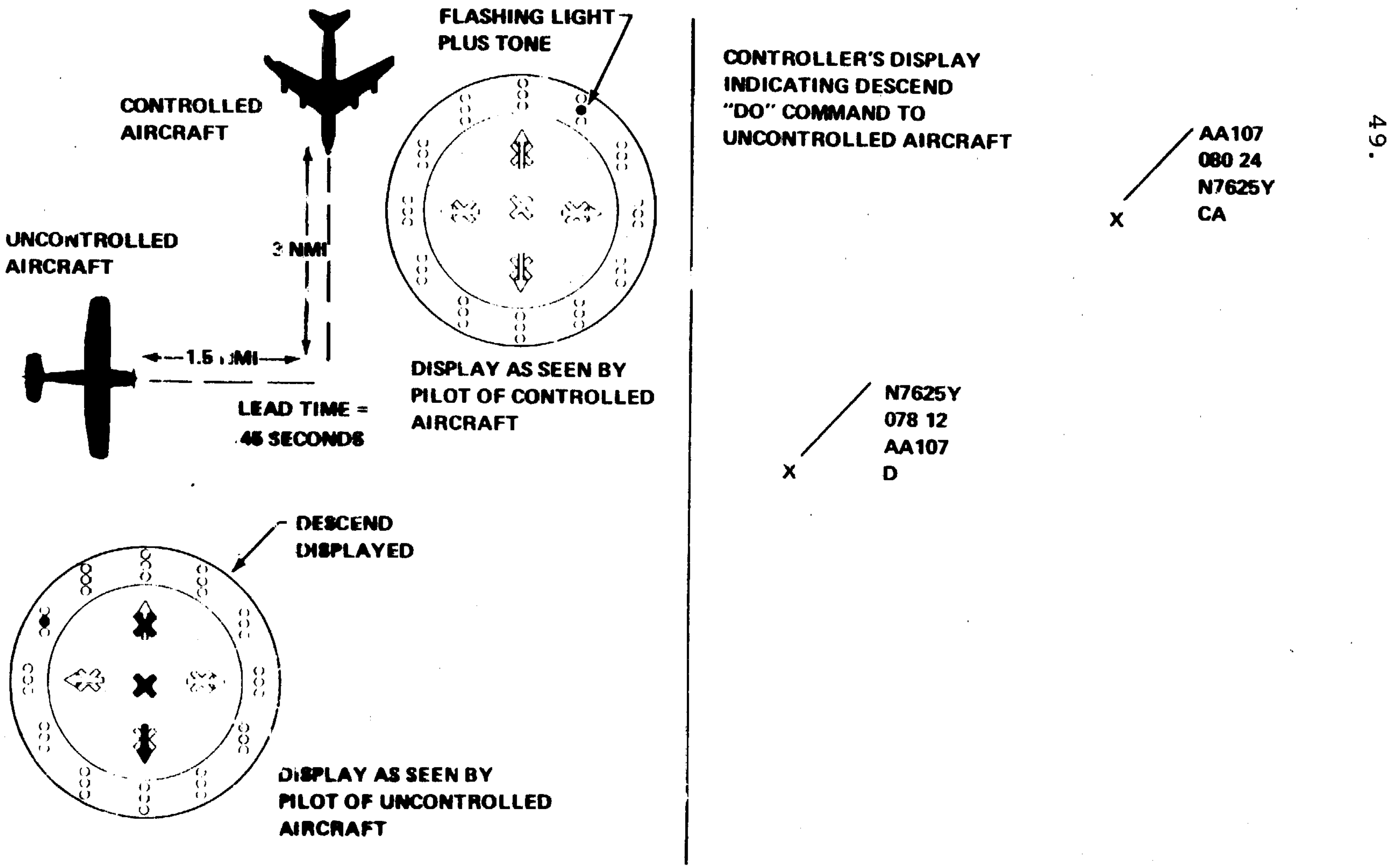


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# IPC

- GROUND-BASED COLLISION AVOIDANCE SYSTEM. INDEPENDENT BACK-UP.
- USES DABS FOR IMPROVED SURVEILLANCE AND DABS DATA LINK FOR TRANSMISSION OF COMMANDS TO AIRCRAFT.
- IPC PROVIDES PROTECTION AGAINST ALL OTHER IPC, DABS, OR ATCRBS EQUIPPED AIRCRAFT WITHIN GROUND SURVEILLANCE. ICAO COMPATIBLE.
- BEST PERFORMANCE OF ALL SYSTEMS, PARTICULARY IN HIGH DENSITY AREAS. THREE DIMENSIONAL SYSTEM.
- IPC ADAPTABLE TO CHANGES IN ATC PROCEDURES; ELIMINATES ATC COMPATIBILITY PROBLEMS.
- OFFERS OPTIONAL PROTECTION TO GENERAL AVIATION AT LOW INCREMENTAL COST ($300 TO $450).

# V. IPC - Program

| | | |
|---|---|---|
| **DESIGN AND FEASIBILITY TESTING** | | COMPLETE |
| = IPC FLIGHT TESTS (SINGLE-SITE) | 1/76 | |
| = IPC SIMULATIONS (MULTI-SITE) | 11/75 | |
| **PROTOTYPE DEVELOPMENT** | | 6/79 |
| = CONTRACT FOR MULTI-SITE SYSTEM | 2/76 | |
| = DABS NATIONAL STANDARD | 7/78 | |
| = SINGLE-SITE SPECIFICATION | 1/77 | |
| = OPERATIONAL TRIALS (PHILADELPHIA) | 8/77 | |
| = MULTI-SITE SPECIFICATION | 6/79 | |
| **IMPLEMENTATION (GROUND)** | | 1980 |
| – FIRST SITE | 6/81 | |
| – AIR CARRIER COVERAGE COMPLETE | 1986 | |
| – GENERAL AVIATION COVERAGE COMPLETE | 1989 | |

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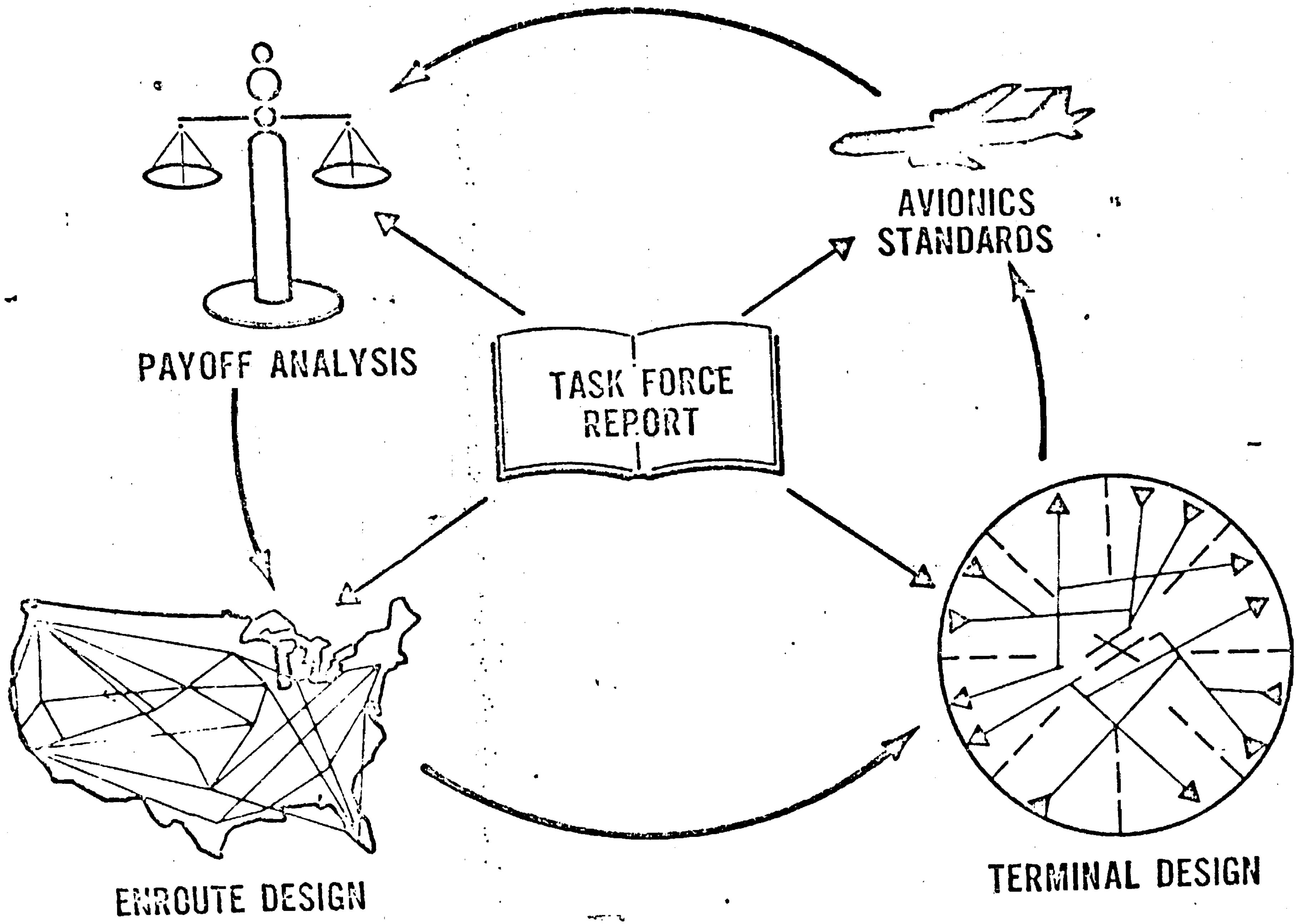
APPENDIX D

(1)

# FAA
# AREA NAVIGATION
# ENGINEERING AND
# DEVELOPMENT

# MAJOR PRODUCT AREAS



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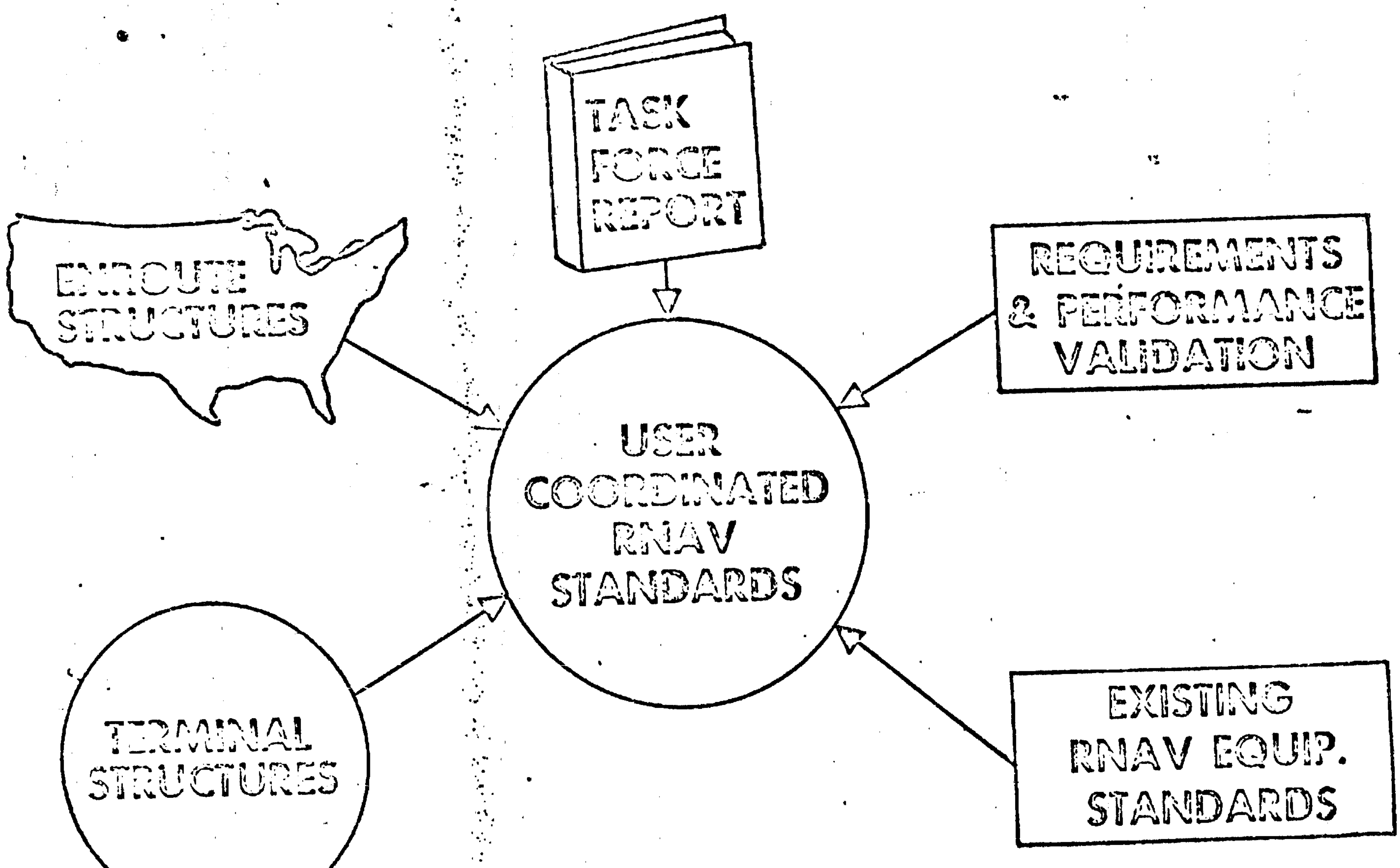
# RNAV AVIONICS STANDARDS



# RNAV AVIONICS
## EXISTING AVIONICS DOCUMENTATION

| | | |
|---|---|---|
| RTCA SC-116E | | |
| | DO-140 (2D) | 8-14-69 |
| | DO-152 (3D) | 3-17-72 |
| ARINC | | |
| | 581 (MARK 1) | 6-30-70 |
| | 582 (MARK 2) | 8-10-70 |
| | 583 (MARK 13) | 8-21-73 |
| FAA | | |
| | AC-90-45 (2D) | 8-18-69 |
| | AC-90-45A (2D & 3D) | 2-21-75 |
| RNAV TASK FORCE REPORT | | 2-23-73 |

# RNAV AVIONICS

## ISSUES

- FLIGHT TECHNICAL ERROR
  - DEFINITION
  - QUANTIFICATION
- WAYPOINT STORAGE
  - 2D VS 3D
- TURN ANTICIPATION
  - LATERAL
  - VERTICAL
- PARALLEL OFFSET
  - 2D
  - 3D
- COURSE SELECTION
  - IMPACT VS TYPE
- SLANT RANGE ERROR
  - IMPACT VS REQUIREMENT
- ACCURACY
  - 2D
  - 3D

# RNAV AVIONICS

* DEVELOPMENT OF INDUSTRY COORDINATED 2D/3D RNAV AVIONICS STANDARDS

* DEVELOPMENT OF INDUSTRY COORDINATED 4D RNAV AVIONICS STANDARDS

# RNAV AVIONICS

## FLIGHT TECHNICAL ERROR

- o BASIC CONSIDERATIONS
  - ● VALIDATE OR MODIFY TASK FORCE FTE VALUES
  - ● QUANTIFY IMPACT OF FTE ON TOTAL SYSTEM ERROR

## TURN ANTICIPATION

- o TASK FORCE RECOMMENDATION
  - ● COUPLED ONLY
- o AC 90-45A RECOMMENDATION
  - ● PROCEDURAL - MANUAL
  - ● COUPLED EQUIVALENT

# RNAV AVIONICS

## PARALLEL OFFSETS

- o TASK FORCE RECOMMENDATION
  - GRANULARITY
  - CONSTANT RADIUS
  - PARELLELING IN TURNS

## SLANT RANGE ERROR CORRECTION

- o TASK FORCE RECOMMENDATION
  - REQUIRED AT OR ABOVE FL 180
  - BELOW FL 180, COMPENSATE BY ROUTE DESIGN

## SYSTEM ACCURACY

- o RECOMMENDATION
  - ENROUTE - $\pm$ 4 NM CONSTANT
  - TERMINAL - $\pm$2 NM CONSTANT

# RNAV AVIONICS

## COURSE SELECTION

- o TASK FORCE RECOMMENDATION
  - NOT SPECIFICALLY INCLUDED IN RSS ERROR BUDGET
- o CONSIDERATIONS
  - OBS INPUT ERROR CAN BE SIGNIFICANT AND SHOULD BE INCLUDED IN RSS
  - STANDARD 3" CARD TYPE OBS RESOLUTION IS INSUFFICIENT FOR CURRENT AND FUTURE ROUTE WIDTHS
  - DIGITAL COURSE SELECTION MAY BE REQUIRED

# RNAV AVIONICS

## WAYPOINT STORAGE

- o TASK FORCE RECOMMENDATION
  - 2D - 6 OR MORE
  - 3D - 10 OR MORE

ANTICIPATED DATA SOURCES

| FLIGHT TESTS | | SIMULATOR TESTS |
|---|---|---|
| Operational | Experimental (Accuracy and Conceptual) | Functional and Accuracy |
| CTI Aero Comm/King (MIA/DEN) | NAFEC Aero Comm/Air Data | U. of Ill. GAT-2/mini comp. |
| NAFEC G-I/Collins (DEN/ORD) | NAFEC G-I (N376)/Collins | NAFEC GAT-2A/King |
| UAL DC-10/Delco (DEN/ORD) | NAFEC G-I (N377)/EDO | NAFEC GAT-2B/EDO |
| | NAFEC 727/Litton | |
| | NAFEC G-I/Butler | |
| | CTI Aero Comm/King Baseline | |
| | NASA 737 (TCV) | |

## RNAV AVIONICS

### A. OPERATIONAL (FIELD) FLIGHT TESTS

| AIRCRAFT/EQUIPMENT | OBJECTIVES |
|---|---|
| AC-500/KING (CTI) | 1. PROCEDURAL FTE DATA AND RNAV FUNCTIONAL CAPABILITIES IN AN OPERATIONAL ENVIRONMENT |
| G-1/COLLINS (FAA) | 2. EVALUATION OF THE OPERATIONAL FEASIBILITY OF "TYPICAL" RNAV TERMINAL AREA ROUTES |
| DC-10/DELCO (UAL) | 3. ASSESSMENT OF THE ABILITY TO EXECUTE THE TASK FORCE RECOMMENDED RNAV MANEUVERS IN THE EXISTING ATC AIRSPACE LIMITS |
| | 4. TERMINAL AREA ROUTE WIDTH AND FTE ERROR BUDGET RECOMMENDATIONS |

# RNAV AVIONICS

## B. EXPERIMENTAL FLIGHT TESTS (CONTINUED) (ON-GOING AND PLANNED)

| AIRCRAFT/EQUIPMENT | OBJECTIVES |
| --- | --- |
| G-1 & 880/COLLINS (FAA) | 1. FTE AND TOTAL SYSTEM ERROR EVALUATION |
| | 2. MULTIPLE WAYPOINT SYSTEM |
| | 3. SENSOR ACCURACY ASSESSMENT |
| | 4. 3D AND 4D (CONVENTIONAL INSTRUMENTS) |
| G-1/EDO (FAA) | 1. FTE AND TOTAL SYSTEM ERROR (2D AND 3D) |
| | 2. PARALLEL OFFSETS |
| | 3. WAYPOINT STORAGE VARIATION (6-20) |
| | 4. TURN ANTICIPATION |
| B-737/HYBRID (NASA/FAA) | 1. 3D AND 4D WITH EADI AND MAP DISPLAY |
| | 2. MAP DISPLAY WITH VARIOUS LEVELS OF INFORMATION |
| | 3. EADI WITH VARIOUS SYMBOLOGY |
| | 4. HIGH ALTITUDE FTE |

## RNAV AVIONICS

### B. EXPERIMENTAL FLIGHT TESTS COMPLETED

| AIRCRAFT/EQUIPMENT | OBJECTIVES |
|---|---|
| G-1/BUTLER (FAA) | 1. QUANTIFY VNAV ERRORS IN ALL PHASES OF FLIGHT |
| | 2. DETERMINE LATERAL AND VERTICAL FTE |
| | 3. EFFECTS OF RADIAL VS NON-RADIAL FLIGHT |
| | 4. VOR/DME EVALUATION |
| AC-500/KING (CTI) | 1. LATERAL AIRSPACE REQUIREMENTS FOR RNAV |
| | 2. RNAV WORKLOAD, BLUNDER POTENTIAL AND FTE BASELINE DATA |
| | 3. PROCEDURAL TURN ANTICIPATION |
| | 4. IMPROMPTU WAYPOINT PROCEDURES |
| AC-680 E/AIR DATA (FAA) | 1. VALIDATION OF BASELINE FLIGHT TEST RESULTS |
| | 2. WAYPOINT STORAGE VARIATION (1,2,3) |
| | 3. SIMPLIFIED RNAV ROUTES |
| | 4. 2D PROCEDURES ONLY |

# FLIGHT SIMULATOR EXPERIMENTS

| SIMULATOR/EQUIPMENT | OBJECTIVES |
|---|---|
| GAT II/Min. Comp. (U. of I.) | 1. Waypoint Storage (1, 2, 3)<br>2. FTE Quantification<br>3. Turn Anticipation Techniques |
| GAT II/King (FAA) | 1. Procedural Turn Anticipation<br>2. Parallel Offsets (Offset Needle)<br>3. Flight Test Correlation |
| GAT II/EDO (FAA) | 1. FTE (CDI vs FD)<br>2. Waypoint Storage (6-20)<br>3. Flight Test Correlation |
| GAT II/4D (FAA) | 1. Time Control<br>2. DSF/Controller Interaction |

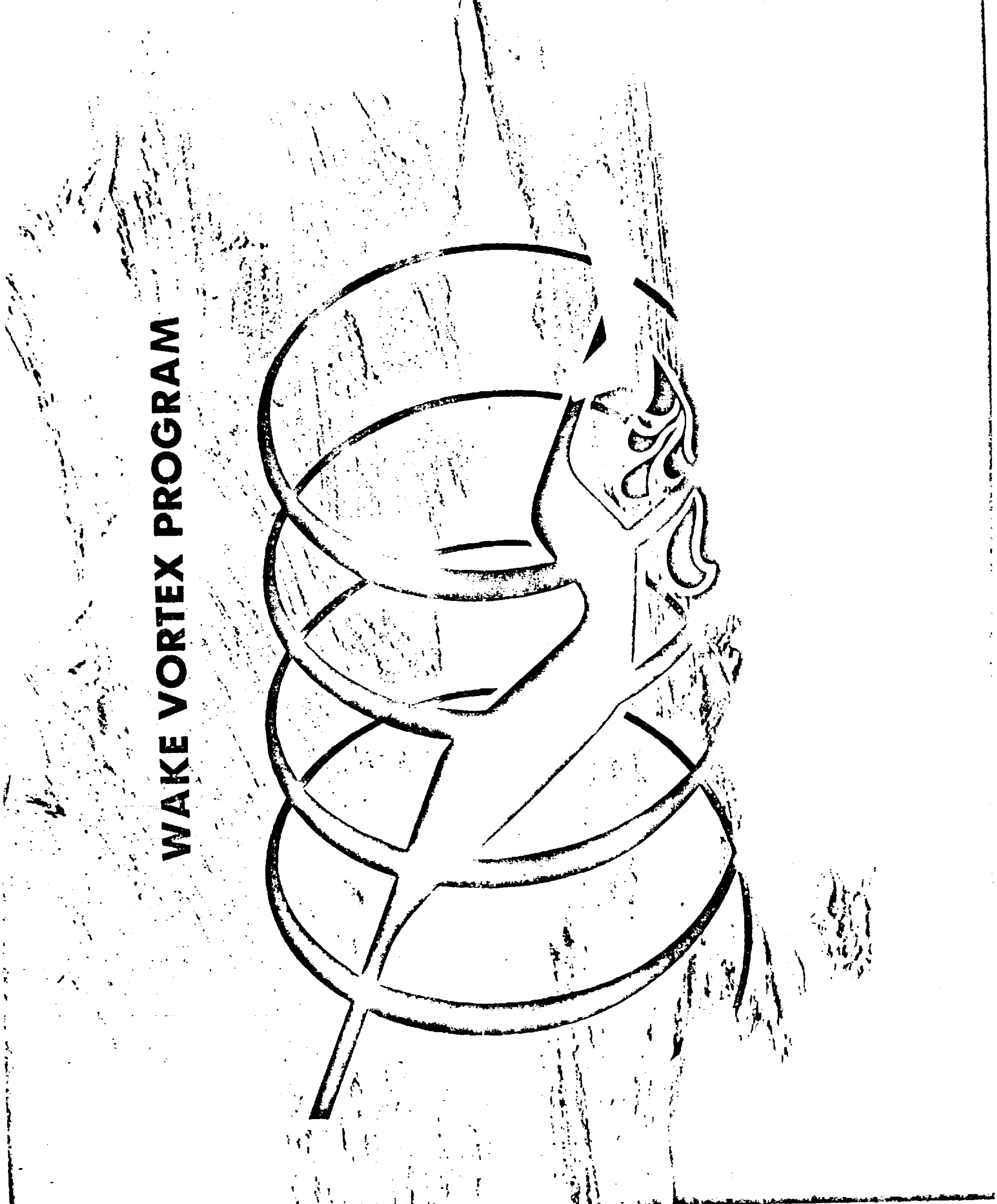
## RNAV AVIONICS

| | FLIGHT TESTS | | | | | SIMULATION TESTS | | |
|---|---|---|---|---|---|---|---|---|
| | AC-680 AIR DATA | G-1 EDO | G-1 COLLINS | AC-500 KING | B-737 TCV | GAT-II MINI-COMP. | GAT-II KING | GAT-II EDO |
| FLIGHT TECHNICAL ERROR | X | X | X | X | HIGH ALTITUDE | X | X | X |
| WAYPOINT STORAGE | 1, 2, 3 WAYPOINT | 1-20 WAYPOINT | | 1 WAYPOINT | | 1, 2, 3 WAYPOINT | 1 WAYPOINT | 1-20 WAYPOINT |
| ANTI-CIPATION | PROCEDURAL | AIDED | AUTO | PROCEDURAL | AUTO | AIDED AND PROCEDURAL | PROCEDURAL | AIDED |
| PARALLEL OFFSET | PROCEDURAL | X | X | PROCEDURAL | X | PROCEDURAL | PROCEDURAL | X |
| COURSE SELECTION | | OBS CARD | | OBS CARD | | DIGITAL | OBS CARD | DIGITAL |
| SLANT RANGE ERROR | X | X | | X | | | | |
| ACCURACY | X | X | X | X | X | X | X | X |

# RNAV AVIONICS

## FUTURE PLANS

- 2D/3D PRELIMINARY MOC INDUSTRY COORDINATION
- ADDITIONAL 2D/3D TESTING AND ANALYSIS
- 4D TESTING AND ANALYSIS
- PRELIMINARY 4D MOC


WAKE VORTEX PROGRAM

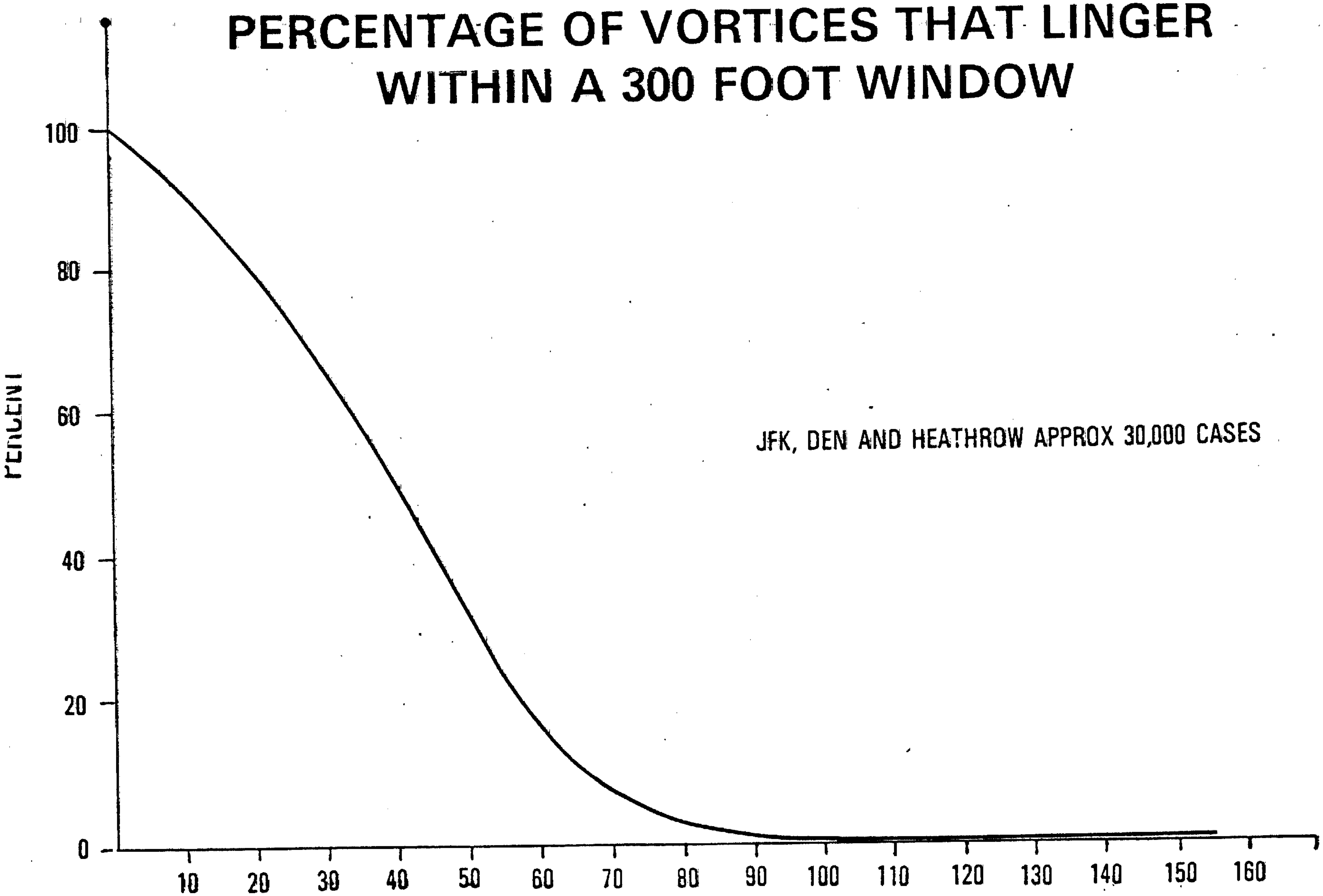
# OBJECTIVE

- INCREASED CAPACITY
  - ELIMINATE OR MINIMIZE THE EFFECTS OF WAKE TURBULENCE AS AN IMPEDIMENT TO TRAFFIC FLOW WITHOUT COMPROMISING SAFETY

# PROGRAM CONCEPT

- MOST VORTICES MOVE QUICKLY OFF FLIGHT PATH

# PERCENTAGE OF VORTICES THAT LINGER WITHIN A 300 FOOT WINDOW



# PROGRAM CONCEPT

- LIFE, INTENSITY, AND MOVEMENT OF VORTICES CAN BE PREDICTED BASED ON KNOWLEDGE OF AIRCRAFT, METEOROLOGICAL, AND TERRAIN PARAMETERS

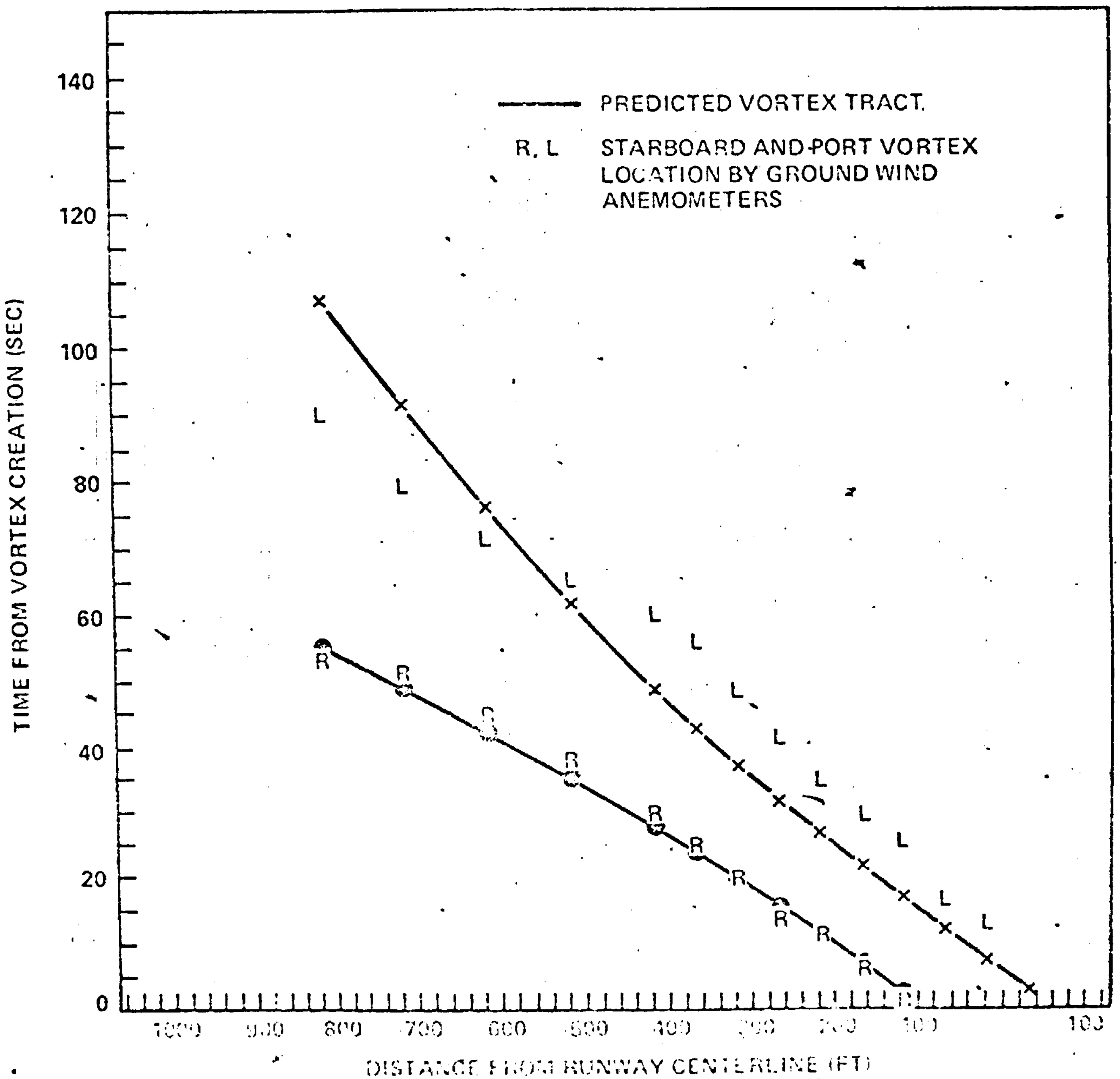
Reprographic Products | New York, N.Y. 10020

CAT. NO. 253-201

# PROGRAM CONCEPT

- VORTICES CAN BE DETECTED AND TRACKED BY SENSORS NOW UNDER DEVELOPMENT

[illegible] VORTEX [illegible] FOR B-747 APPROACH
TO RUNWAY 31R AT JFK

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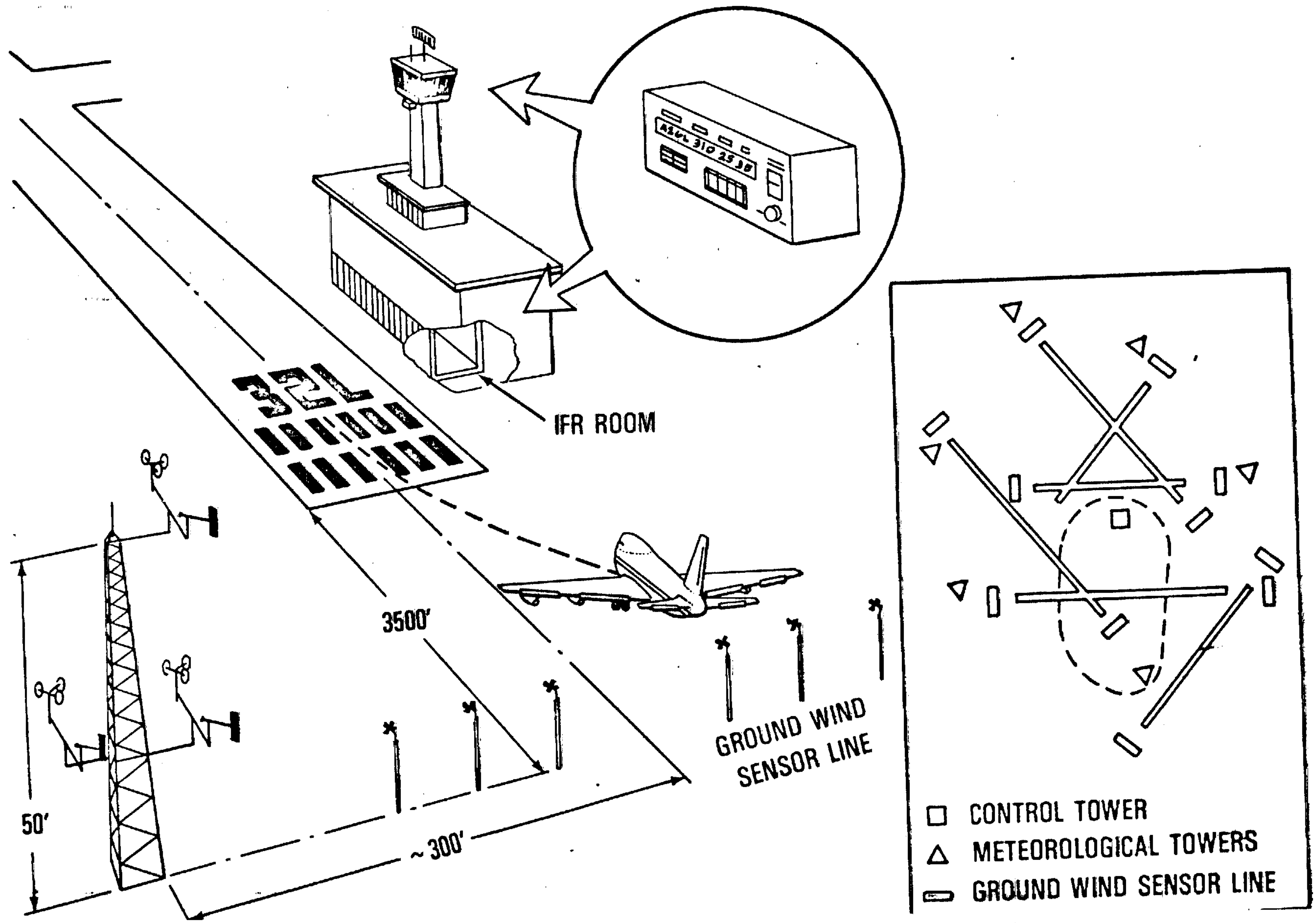
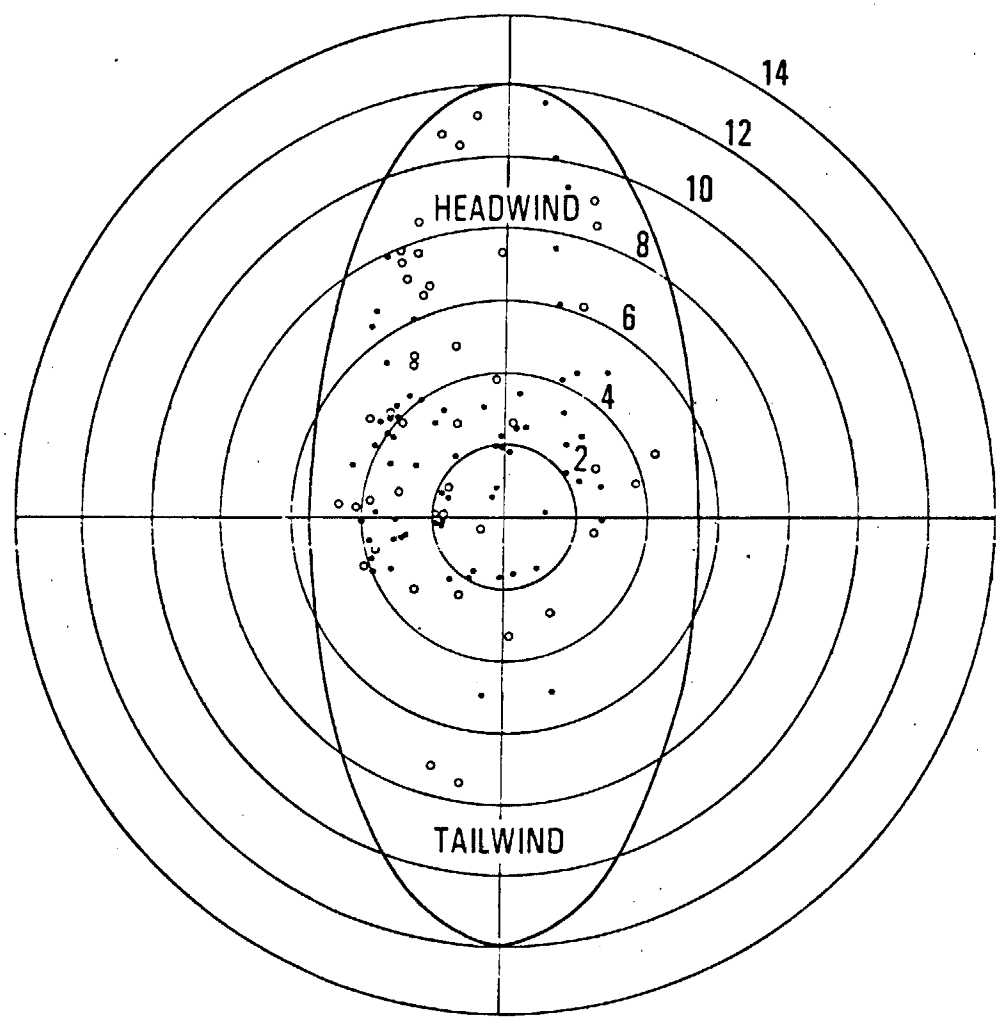
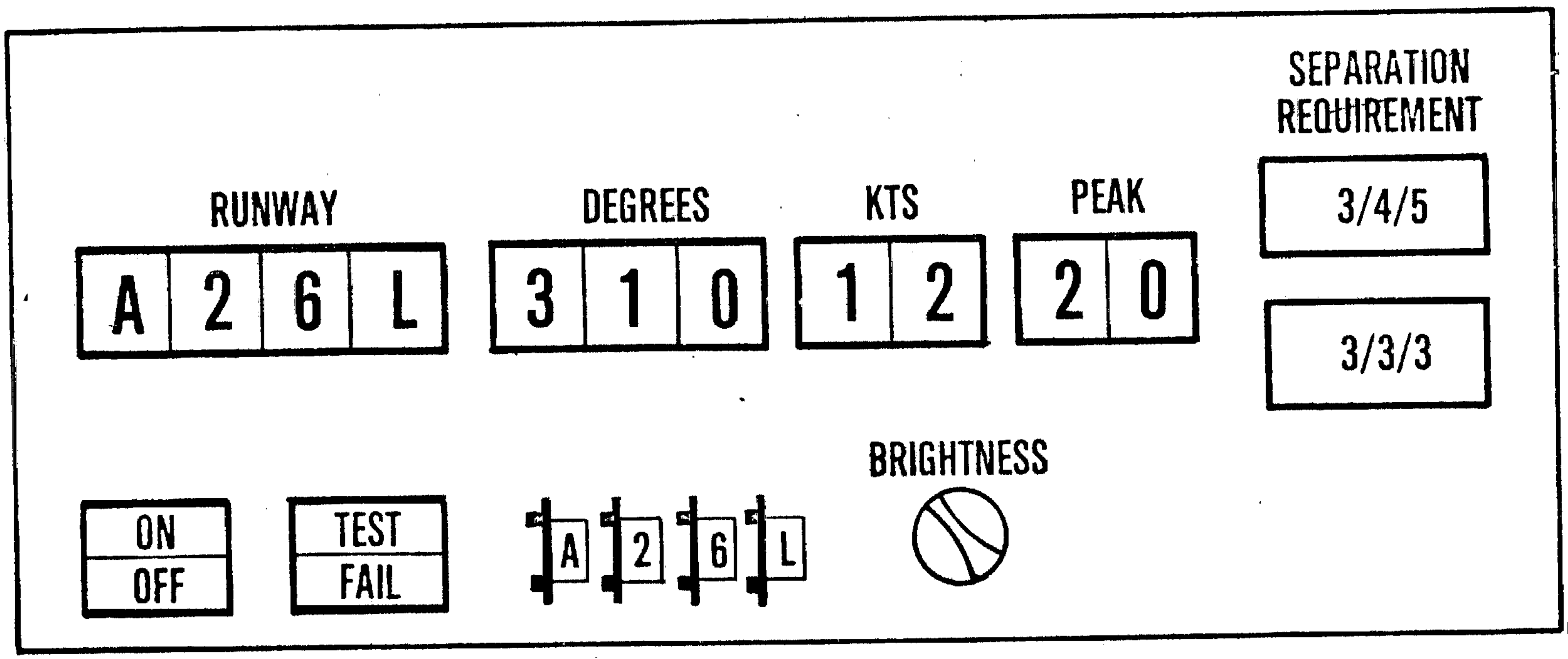
# VORTEX ADVISORY SYSTEM (VAS)

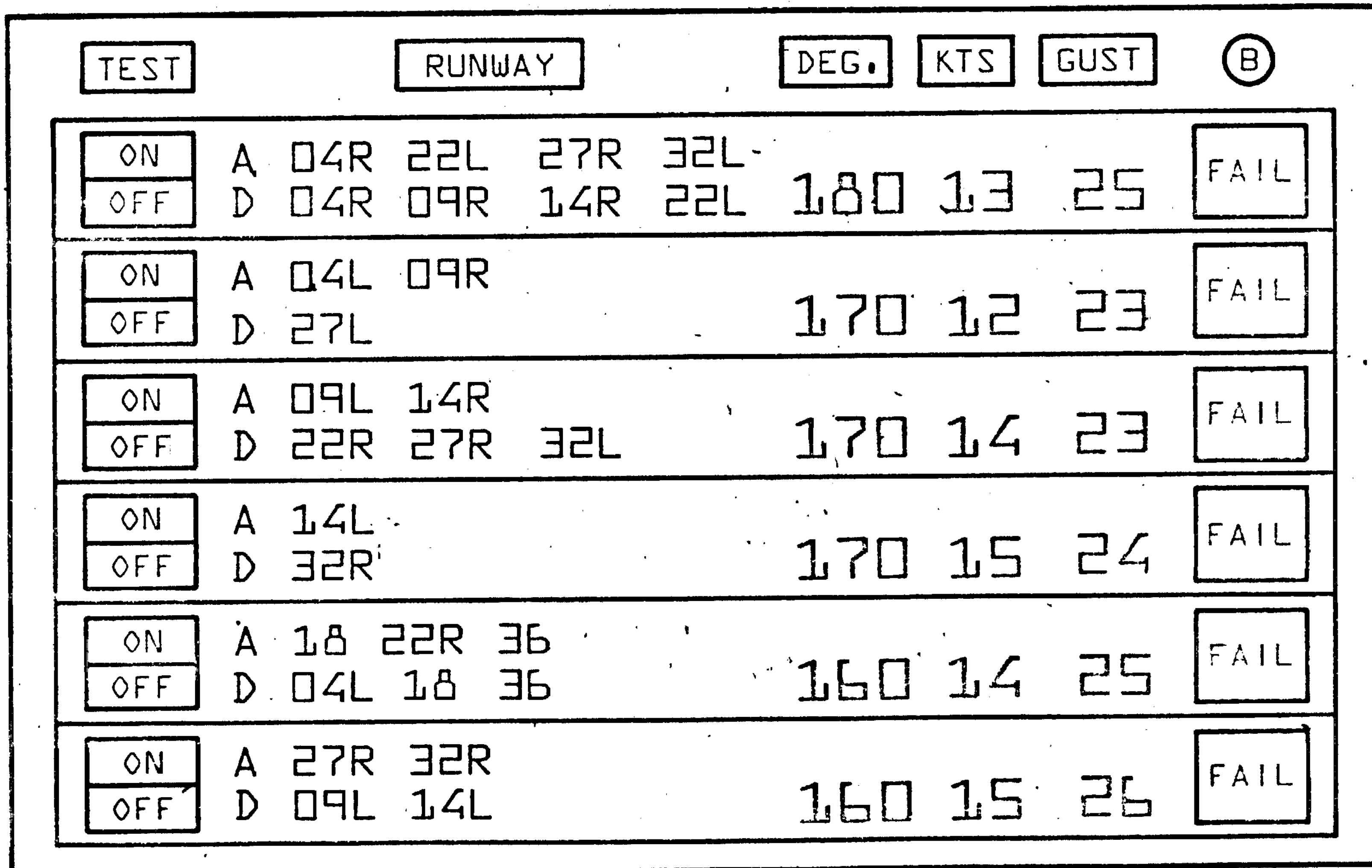


# VORTEX ADVISORY SYSTEM WIND SPEED AND DIRECTION ALGORITHM

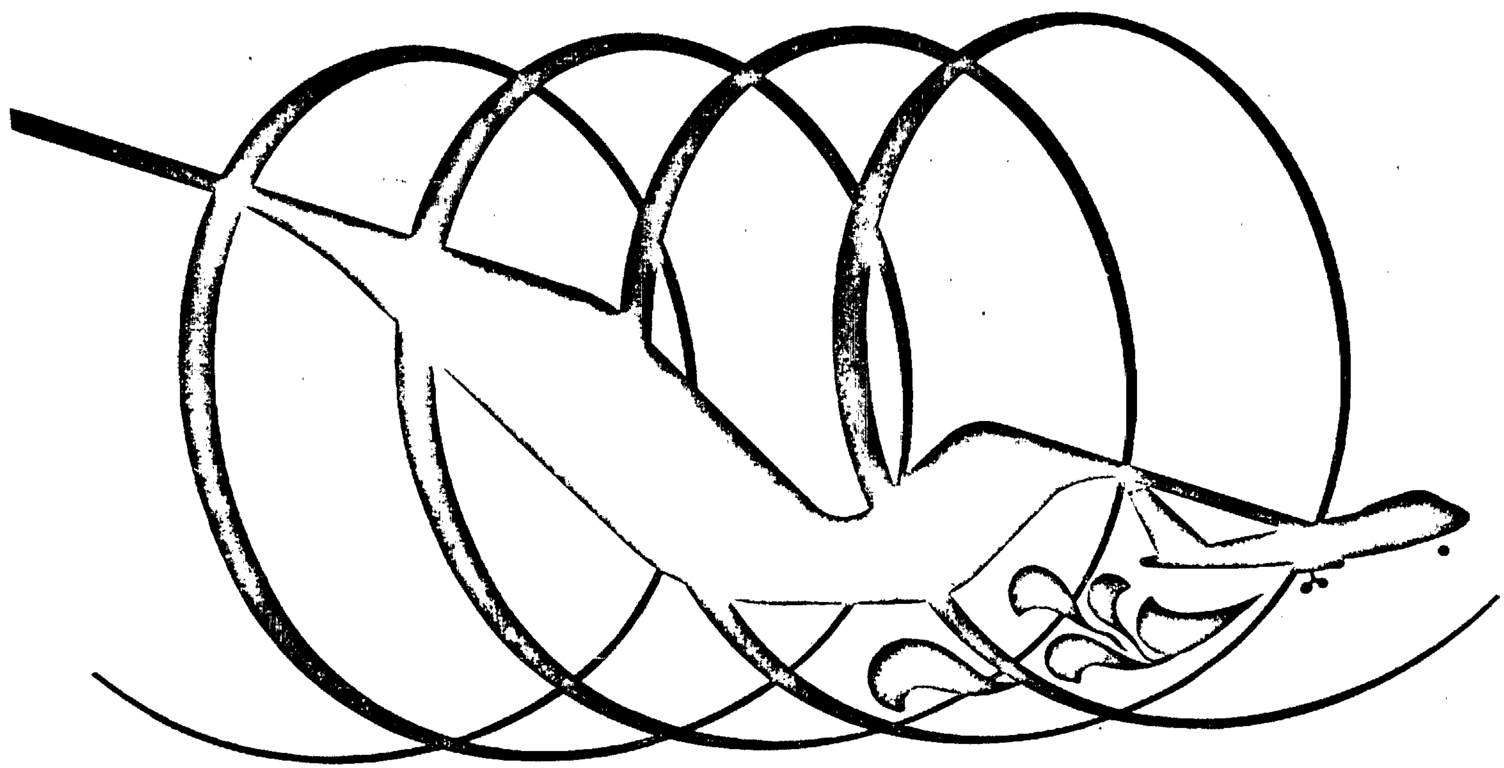


# VORTEX ADVISORY SYSTEM DISPLAY




TEST
RUNWAY
DEG.
KTS
GUST
B
ON OFF
A 04R 22L 27R 32L
D 04R 09R 14R 22L
180 13 25
FAIL
ON OFF
A 04L 09R
D 27L
170 12 23
FAIL
ON OFF
A 09L 14R
D 22R 27R 32L
170 14 23
FAIL
ON OFF
A 14L
D 32R
170 15 24
FAIL
ON OFF
A 18 22R 36
D 04L 18 36
160 14 25
FAIL
ON OFF
A 27R 32R
D 09L 14L
160 15 26
FAIL

# WIND SHEAR PROGRAM



# AIRCRAFT ACCIDENTS WITH CONTRIBUTING WIND SHEAR INVOLVEMENT ('71-'75)

| DATE | LOCATION | AIRCRAFT TYPE | PROBABLE TYPE OF WIND SHEAR | NTSB RPT DATE |
|---|---|---|---|---|
| JAN 4 1971 | LAGUARDIA A/P NEW YORK CITY | DOUGLAS DC-3 | FRONTAL SHEAR DIMINISHING TAILWIND SHEAR | JUN 3 1971 |
| JULY 23 1973 | LAMBERT IAP ST LOUIS | FAIRCHILD-HILLER FH-227B | GUST FRONT SHEAR THUNDERSTORM IN VICINITY | APR 24 1974 |
| NOV 27 1973 | CHATTANOOGA MUNI CHATTANOOGA | MCDONNELL-DOUGLAS DC-9 | GUST FRONT SHEAR THUNDERSTORM SOUTHEAST | NOV 8 1974 |
| DEC 17 1973 | LOGAN IAP BOSTON | MCDONNELL-DOUGLAS DC-10 | FRONTAL SHEAR TAILWIND TO HEADWIND SHEAR | NOV 8 1974 |
| JUNE 24 1975 | JFK INT'L A/P NEW YORK CITY | BOEING B-727 | GUST FRONT SHEAR THUNDERSTORMS IN AREA | 1/ — |
| 2/AUG 7 1975 | STAPLETON IAP DENVER | BOEING B-727 | GUST FRONT SHEAR THUNDERSTORM NORTHWEST | 1/ — |

1/ NTSB AIRCRAFT ACCIDENT REPORT NOT RELEASED

2/ TAKE-OFF/DEPT ACCIDENT

WIND SHEAR PROGRAM

# OBJECTIVE

REDUCE/ELIMINATE THE HAZARDS CREATED BY LOW-LEVEL WIND SHEAR IN THE TERMINAL AREA

*HOW?*

- WARN PILOTS OF POTENTIAL HAZARDOUS WIND SHEAR ENCOUNTERS
- PROVIDE ON-BOARD FLIGHT DETECTION & CONTROL GUIDANCE FOR WIND SHEAR ENCOUNTERS
- DEVELOP A CAPABILITY TO PREDICT HAZARDOUS WIND SHEAR EVENTS FOR THE NAS

WIND SHEAR PROGRAM

# OBJECTIVE

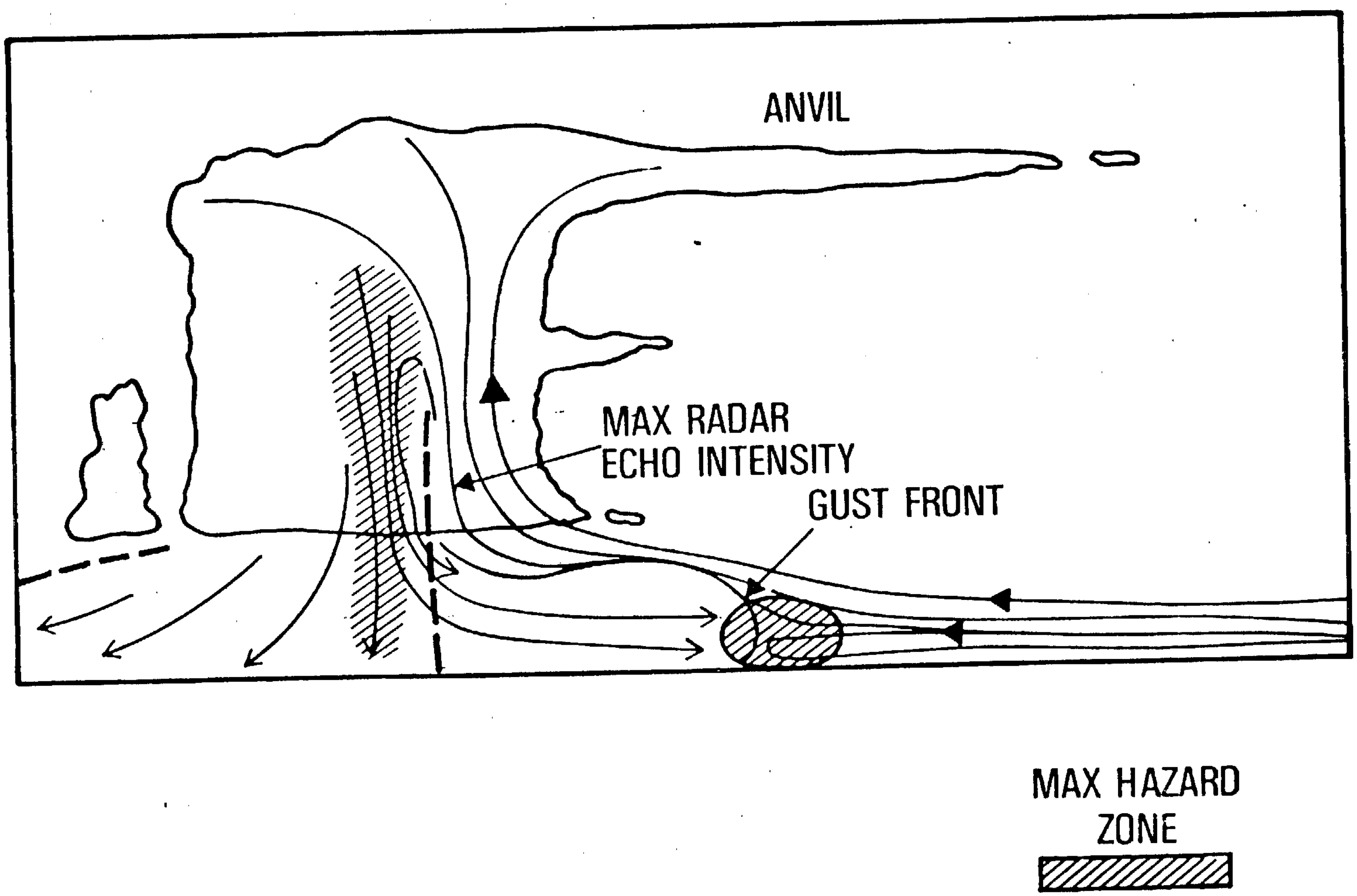
*HOW? (CONT)*

- PROVIDE INFORMATION TO FLIGHT STANDARDS DESCRIBING THE WIND SHEAR HAZARD AS A FUNCTION OF AIRCRAFT TYPE, CONFIGURATION, ALTITUDE, ETC.
- FURNISH DATA TO ATC SYSTEM ON MAGNITUDE OF WIND SHEAR HAZARD IN THE TERMINAL AREA

# WIND SHEAR PROGRAM
## MAJOR CAUSES OF WIND SHEAR

- INVERSION
- FRONTAL PASSAGE
- THUNDERSTORM ACTIVITY

# VERTICAL CROSS SECTION OF A THUNDERSTORM



WIND SHEAR PROGRAM

# WIND SHEAR CHARACTERIZATION

*EXISTING DATA*

- LOW-LEVEL WIND SHEAR PROFILES
- TOWER DATA (DREXEL, SAVANNAH RIVER, SFO, NSSL)
- ANALYSIS OF HASWELL & DENVER DATA)

WIND SHEAR PROGRAM

# HAZARD DEFINITION

## GROUND BASED SENSORS
## AVIONICS

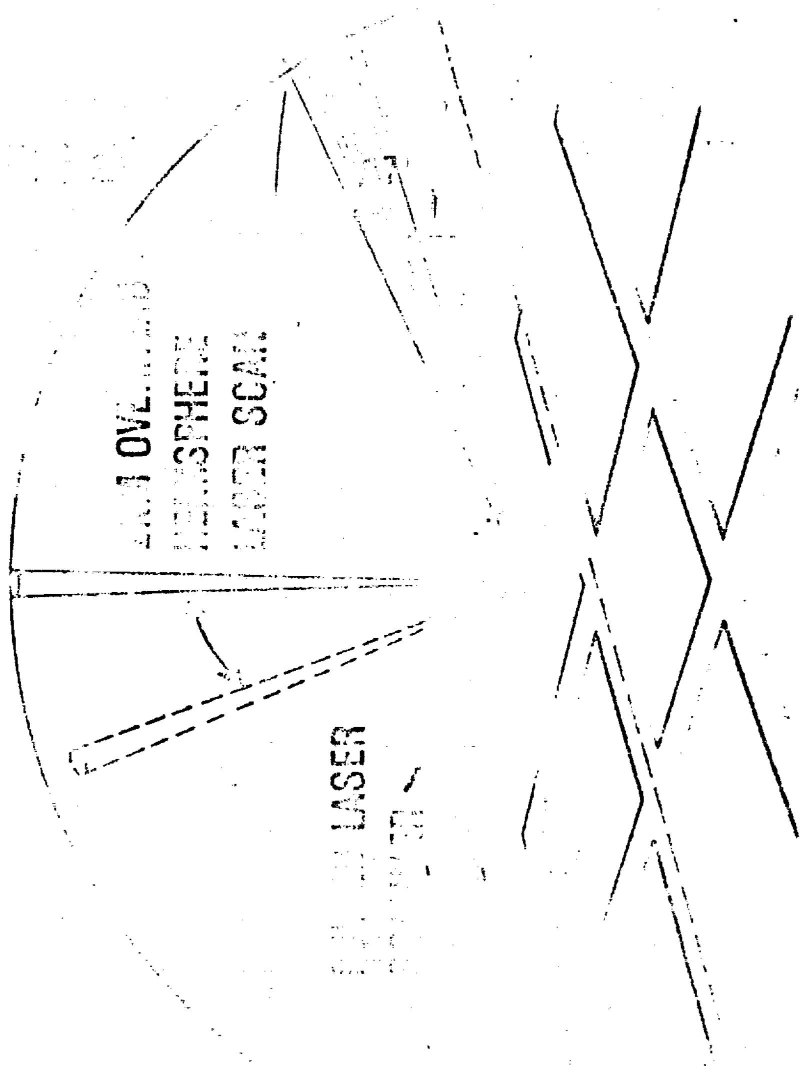
- WIND SHEAR PROFILES
  - CURRENT (INVERSION, FRONTAL, THUNDERSTORM GUST FRONTS)
  - UPDATED (AIRBORNE PROFILES, TOWER AND GROUND BASED SENSOR DATA)
- AIRCRAFT TYPE
- AIRCRAFT CONFIGURATIONS (WT, ANGLE OF ATTACK, AIRSPEED, ETC)
- ALTITUDE OF ENCOUNTER

WIND SHEAR PROGRAM

# GROUND-BASED SENSORS

- GUST FRONT WARNING SYSTEM - PRESSURE JUMP SENSORS: NSSL, O'HARE, DULLES

- VERTICAL PROBES
  - ACOUSTIC DOPPLER RADAR - TABLE MT & DULLES
  - CW DOPPLER LASER - LEASED VAN

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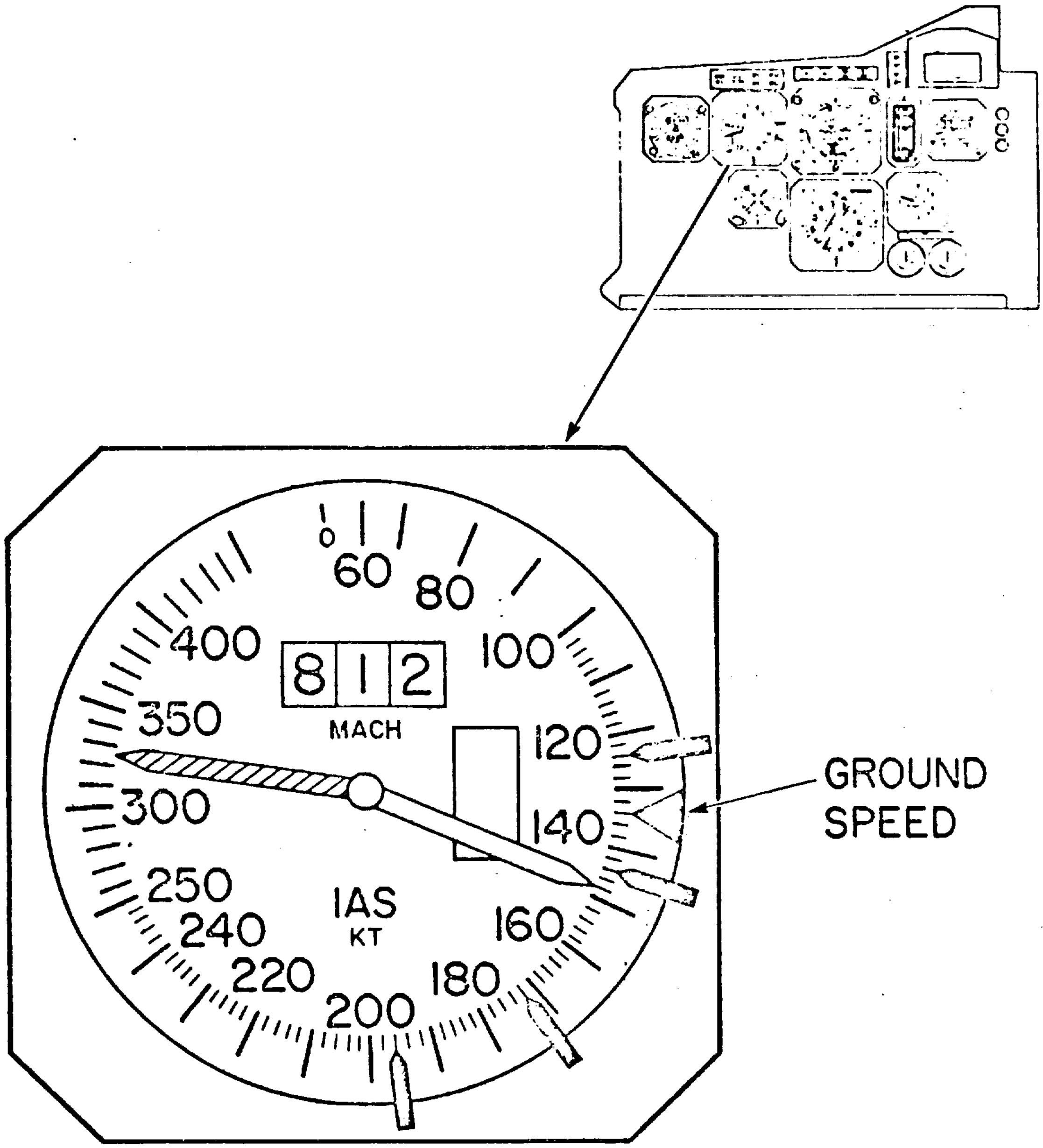
WIND SHEAR PROGRAM

# AVIONICS

| | |
|---|---|
| *PHASE I:* | DC-10 SIMULATIONS<br>ARTS III/DME STUDIES<br>DETECTION/CONTROL ALGORITHM |
| *PHASE II:* | FOLLOW-ON SIMULATIONS<br>HARDWARE DEVELOPMENT |

89.




MACH/AS INDICATOR

WIND SHEAR PROGRAM

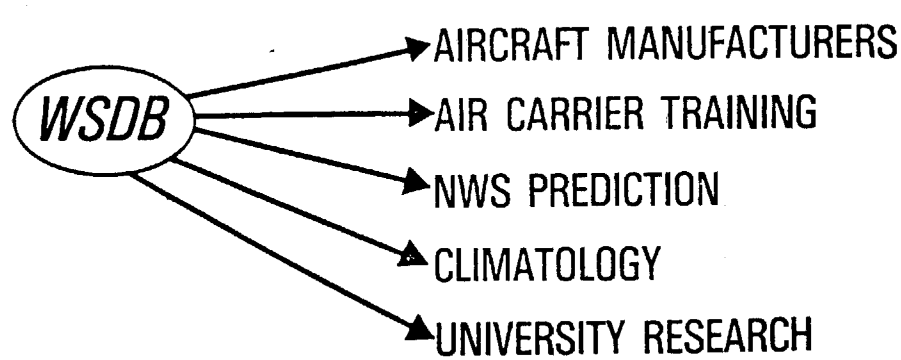
# DATA MANAGEMENT

- DATA MANAGEMENT PLAN
  - DESCRIBES AIRBORNE & GROUND-BASED DATA COLLECTION
  - PROVIDES GUIDANCE ON DATA FORMATS
  - OFFERS DATA BASE ANALYSIS GUIDANCE

WIND SHEAR PROGRAM

# DATA MANAGEMENT (CONT)

- WIND SHEAR DATA BASE (WSDB)
  - AIRBORNE & TOWER PROFILES
  - GROUND BASED SENSOR INPUTS
  - WIND SHEAR DISTRIBUTION & FREQUENCY



WIND SHEAR PROGRAM

# INTEGRATION INTO NAS

- USER REQUIREMENTS
- DISPLAYS
- COMMUNICATIONS
- LANGUAGE DEVELOPMENT
- OPERATING RULES & PROCEDURES
  - ATC
  - PILOTS
  - OTHER

WIND SHEAR PROGRAM

# PREDICTION
# NWS

- **TEST OF FRONTAL SPEED/$\Delta$ TEMP TECHNIQUE**
  - FIVE EAST COAST TERMINALS (JFK, LGA, EWR, DCA, & IAD)
  - TWO CHICAGO AIRPORTS (ORD & MDW)
- **EXPAND NATIONWIDE**
- **LONGER TERM DEVELOPMENTS**
  - SHEAR INTENSITIES
  - THUNDERSTORM GUST FRONTS

# COCKPIT HUMAN FACTORS

## PROBLEM

NTSB DATA ON PILOT ERROR AS CASUAL OR CONTRIBUTING FACTOR IN FATAL ACCIDENTS:

AIR CARRIER

1970 - 1972 - 59%
1974 - 50%

GENERAL AVIATION

1972 - 86%
1973 - 89%

# COCKPIT HUMAN FACTORS

## RECOMMENDATION 10

- SPECIAL TASK FORCE ON FAA SAFETY MISSION - JANUARY 1975
- 19 RECOMMENDATIONS:
- NOS. 18, 10 ------ ADVANCED R&D PROGRAMS WITHIN FAA
- NO. 18 ------ ADVANCED SYSTEMS ENGINEERING PROGRAM
- NO. 10 ------ RESEARCH PROGRAM FOR OPTIMIZING CREW PERFORMANCE AND MINIMIZING HUMAN ERROR IN AIRCRAFT COCKPITS

"FAA MUST UNDERTAKE A MAJOR SAFETY RESEARCH PROGRAM TO ASSURE THAT FUTURE AIRCRAFT DESIGNS MAKE OPTIMUM USE OF CREW CAPABILITIES, AND TO ENSURE THAT FUTURE SYSTEMS ARE DESIGNED AROUND REASONABLE CRITERIA FOR HUMAN ERROR."

# COCKPIT HUMAN FACTORS

## OBJECTIVES

1. PROVIDE IMPROVED TECHNICAL BASIS FOR MINIMIZING HUMAN ERROR AND ENHANCING HUMAN PERFORMANCE IN THE COCKPITS OF CURRENT GENERATION TRANSPORT AND GENERAL AVIATION AIRCRAFT.

2. PROVIDE IMPROVED TECHNICAL BASIS FOR THE DESIGN AND CERTIFICATION OF THE MAN/MACHINE INTERFACE IN FUTURE AIRCRAFT COCKPITS.

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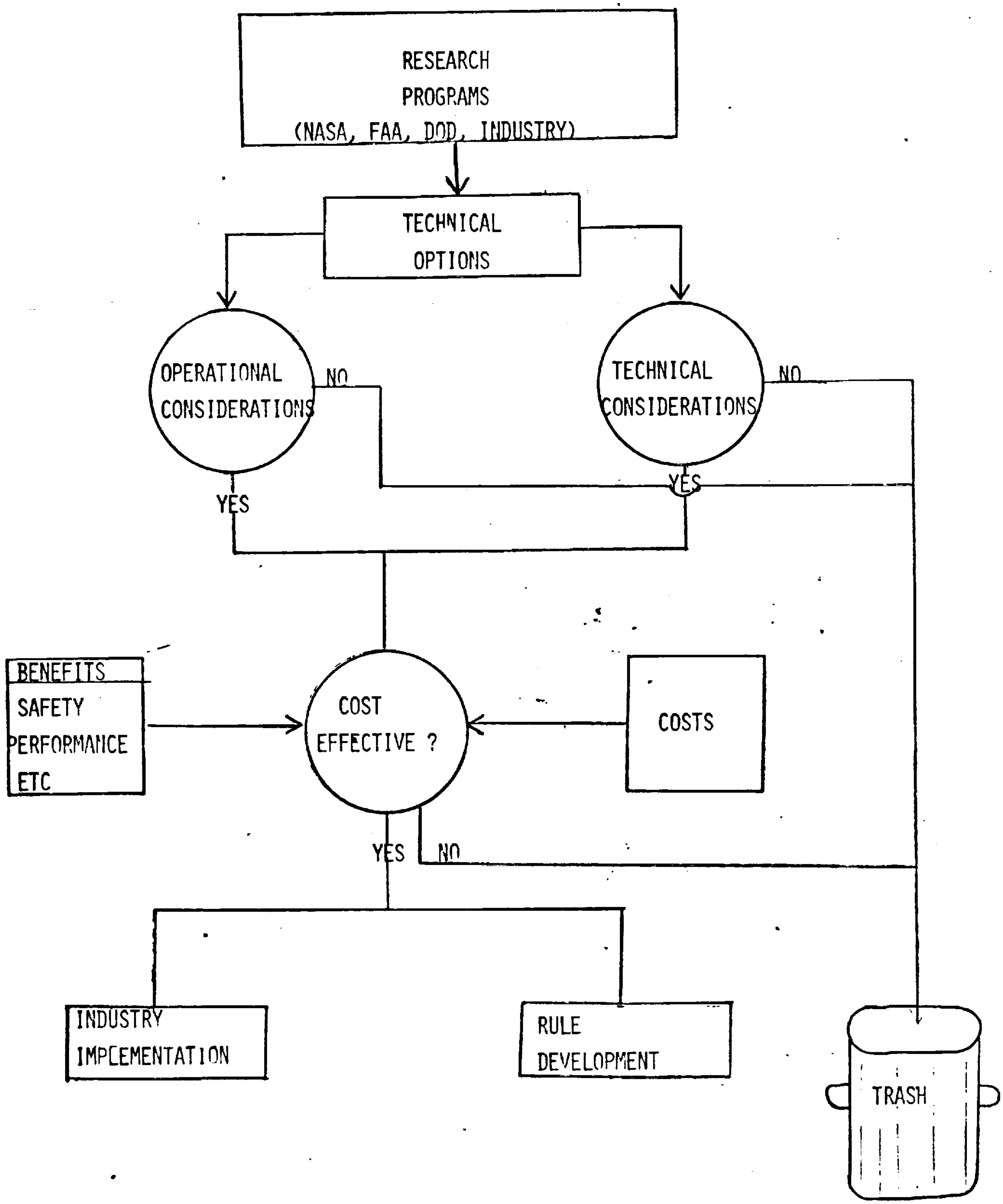
COCKPIT HUMAN FACTORS

APPROACH



## COCKPIT HUMAN FACTORS

### TECHNICAL PROGRAM/STATUS

PHASE I - REVIEW EXISTING COCKPIT HUMAN FACTORS RESEARCH

- o FAA - COMPLETE
- o NASA - COMPLETE
- o DOD - IN PROGRESS
- o INDUSTRY - IN PROGRESS

## TECHNIAL PROGRAM/STATUS (CONT'D)

PHASE II - PROGRAM FOR CURRENT AIRCRAFT

1. ADVANCED HAZARD DETECTION AND WARNING
   - o SRDS/BOEING - IN PROGRESS, FUNDED
   - o AMES/FAA - IN DEFINITION, UNFUNDED
   - o OSEM - IN DEFINITION, UNFUNDED
2. IMPROVED VERTICAL GUIDANCE
   - o HUD'S - SRDS PROGRAM IN DEFINITION, FUNDED
   - o VISUAL SYSTEMS - FAME TESTING IN PROGRESS
3. ADVANCED DISPLAYS
   - o CDTI, RNAV, EADI, EHSI - PROGRAMS IN PROGRESS
   - o WVAS, M&S, ASA, DABS - PROGRAMS IN DEFINITION
     DATA LINK, ENERGY/FUEL MANAGEMENT,
     GPWS, MLS
4. HUMAN FACTORS OF CREW PROCEDURES, TRAINING, HUMAN PERFORMANCE
   - o NASA PROGRAM - IN PROGRESS
   - o FAA PROGRAM - BEING CONSIDERED

## TECHNICAL PROGRAM/STATUS (CONT'D)

PHASE III - PROGRAM FOR FUTURE AIRCRAFT - AWAITING APPROVAL OF R-10 DOCUMENT

- o ESTABLISH INTERAGENCY STEERING GROUP
- o DEVELOP LONG-RANGE GOVERNMENT/INDUSTRY RESEARCH PROGRAM
  - FOLLOW-ON TO PHASE II
  - MINIMIZE DUPLICATION
  - MAXIMUM USE OF UNIQUE FACILITIES/EXPERTISE
  - INDUSTRY INVOLVEMENT
  - DRAW ON MILITARY RESULTS
- o MONITOR PROGRAM PROGRESS
- o COORDINATE JOINT PROGRAMS
- o PUBLISH COCKPIT HUMAN ENGINEERING DESIGN HANDBOOKS
- o PREPARE JOINT RECOMMENDATIONS TO FLIGHT STANDARDS ON EXPANSION/ADDITIONS TO PARTS 23, 25, 121, 135, ETC.

APPENDIX H

# FUEL CONSERVATIVE PROFILES

## BACKGROUND

- o ENERGY POLICY AND CONSERVATION ACT - DECEMBER 22, 1975
  - AVIATION GOAL - 10% IMPROVEMENT OVER 1972
  - REPORT FROM FAA ON RESULTS SINCE OCTOBER 1973
- o CONSULTATIVE PLANNING CONFERENCE - "THE ENERGY OUTLOOK FOR AVIATION" SUMMER, 1973
- o PRESIDENTIAL FUEL ALLOCATION PROGRAM
  - SHORT-TERM: FAA 7-POINT PROGRAM (90 DAYS)
    1. REVISED GATE-HOLD PROCEDURES
    2. REVISED FLOW-CONTROL PROCEDURES
    3. OPTIMUM CRUISE
    4. REVISED ATC PROCEDURES
       - HIGHER HOLDING
       - ASSIGNING MORE EFFICIENT CRUISE ALTITUDES
       - MINIMIZING CIRCUITOUS ROUTINGS
    5. TAXIING WITH FEWER ENGINES
    6. EXPANDED USE OF SIMULATORS
    7. AIRPORT DEVELOPMENT

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# FUEL CONSERVATIVE PROFILES

## BACKGROUND (CONT'D)

- o INTERMEDIATE TERM ALTERNATIVES (1974 - 1976)
  - o AIRCRAFT TOWING
  - o IMPROVEMENT OF MAJOR AIRPORT LANDING SYSTEMS
  - o ADDITIONAL/IMPROVED RUNWAY EXITS
  - o OPTIMUM DESCENT PROFILES
  - o REDUCED RUNWAY SPACINGS
- o LONG-TERM ALTERNATIVES (1977 - 1982)
  - o REVISED CLIMB AND DESCENT PROCEDURES
  - o FAD PROCEDURES
  - o RUNWAY CAPACITY CONCEPTS
  - o AIRPORT IMPROVEMENT PROGRAM
  - o APPROACH LIGHT SYSTEMS
    - TIMED LIGHTING SYSTEMS
    - REWIRING TO PERMIT PARTIAL USE OF LIGHTS

# FUEL CONSERVATIVE PROFILES

## BACKGROUND (CONT'D)

- TASK FORCE II REPORT - OPTIONS FOR ADDITONAL 10%

  FAA

  - IMPROVED FLOW CONTROL/FAD PROCEDURES
  - WAKE VORTEX CLASS SEQUENCING
  - WVAS
  - STAGGERED ARRIVALS ON PARALLEL RUNWAYS 4300'
  - EXPANDED USE OF RNAV

  AIRPORTS

  - TEMPORARY RUNWAYS
  - G/A RUNWAYS @ HUBS
  - SNOW/ICE REMOVAL EQUIPMENT

## FUEL CONSERVATIVE PROFILES

### BACKGROUND (CONT'D)

- AIRCRAFT OPERATORS
  - SIMULATORS
  - RESEAT EXISTING AIRCRAFT
  - REDUCED TANKERING
  - OPTIMUM CRUISE
  - OPTIMUM ALTITUDE
  - OPTIMUM DESCENTS
  - TAXI ON FEWER ENGINES
  - LOAD TO AFT CG



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# FUEL CONSERVATIVE PROFILES

## CURRENT PROGRAMS

- LOCAL FLOW CONTROL
  - "FUMES"
  - "BEDPOSTS"
  - MIDNIGHT ROMEO, MOON RIVER GROVE
- NATIONAL FLOW CONTROL
  - FAD PROCEDURES
  - DELAY EQUALIZATION PROCEDURES
- ATC ACCOMMODATION OF FUEL CONSERVATIVE PROFILES
  - ALTITUDE ASSIGNMENTS, DCA/LGA CORRIDOR
  - EFFECTS ON M&S OF DECELERATING APPROACHES/ ENROUTE DESCENTS

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## FUEL CONSERVATIVE PROFILES

### PLANNED PROGRAMS

- o 4D RNAV
- o AIRBORNE PERFORMANCE COMPUTERS
- o IMPROVED WINDS ALOFT
- o AUTOMATION (FLOW CONTROL, SEQUENCING, M&S)
- o ATC ACCOMMODATION
  - ROUTES
  - ALTITUDES
  - CLIMBS/DESCENTS

# AUTOMATED IFR TRAFFIC CONTROL

**OBJECTIVE:** TO DEVELOP SYSTEM CONCEPTS, DESIGN SOFTWARE AND EXPERIMENTALLY EXPLORE THE AUTOMATION OF THE ROUTINE CONTROL OF IFR TRAFFIC.

**APPROACH:**

- GUIDELINES
  - o AUTOMATE THE ROUTINE, NOT THE RARE OR UNUSUAL OCCURRENCE
  - o KEEP THE CONTROLLER FULLY APPRISED
  - o EXPECT THE CONTROLLER TO RETAIN OPERATIONAL RESPONSIBILITY
  - o MAKE THE AUTOMATED SYSTEM FAILURE TOLERANT
- COMPLETE THE FRONT ROYAL SECTOR MODEL
  - o FLIGHT PLAN AND RANDOM ROUTES
  - o CONFLICT DETECTION AND RESOLUTION
    - ALTITUDE CONTROL
    - SPEED CONTROL
    - PATH SHORTENING/LENGTHENING
    - HOLDING
    - PARALLEL OFFSETS

## AUTOMATED IFR TRAFFIC CONTROL (CONT'D)

APPROACH: (CONT'D)

- o DISPLAY AND INTERACTIVE CAPABILITIES
- o SOFTWARE TEST, DEBUG AND EVALUATION AIDS

- VALIDATION EXPERIMENTS
  - o COMPARE ACTUAL FRONT ROYAL DATA: CONTROLLER VS AUTOMATION

- FAST TIME STUDIES
  - o RELATIVE EFFECTIVENESS OF ALTERNATE RESOLUTION STRATEGIES
  - o RELATIVE EFFICIENCY OF ALTERNATE PLANNING STRATEGIES
  - o EVALUATION OF ENROUTE METERING ALGORITHMS
  - o ESTIMATES OF COMPUTER AND COMMUNICATION CAPACITIES AND COSTS

- REAL TIME EVALUATION OF "CONTROLLER AS THE MANAGER" CONCEPT

- HANDOFF TO SRDS FOR EVALUATION/EXPANSION AT NAFEC

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## APPENDIX J

### AD HOC PANEL RECOMMENDATION

CLEARLY DELINEATE PRESENT SYSTEM CAPABILITIES AND SHOW THE PERFORMANCE IMPROVEMENT THAT THE TCV PROGRAM IS PROJECTED TO ACHIEVE.

OBJECTIVE:

I. IMPROVE TERMINAL AREA CAPACITY AND EFFICIENCY

HOW ACHIEVE:

- CAPABILITY FOR SHORTER PRECISION-GUIDED CLOSE-IN CURVED AND DECELERATING APPROACH PATHS
  - BENEFIT: REDUCED TIME, FUEL, AND AIRSPACE; EFFICIENT SEQUENCING
  - TARGET: $\leq$ 1 1/2 MILE STRAIGHT FINAL, VMC-TYPE TERMINAL MANEUVERS
- TIME CONTROLLED ARRIVALS AND FLOW SEQUENCING
  - BENEFIT: REDUCED AIRSPACE AND DELAYS (ELIMINATE PATH STRETCHING AND HOLDING). INCREASED ACCURACY OF ARRIVAL TIME
  - TARGET: ± 5 SECONDS ARRIVAL ACCURACY AT THRESHOLD
- REDUCED TOUCHDOWN DISPERSION (DLC AND EL-2) AND USE PROGRAMED TURNOFFS (AUTO BRAKING AND TURNOFF)
  - BENEFIT: 40 SECOND SPACING AT THRESHOLD (VORTEX ALLEVIATION ASSUMED)
  - TARGET: RUNWAY OCCUPANCY 25 SECONDS, LANDING RATE DOUBLED

- PRECISION TRACKING INTO FINAL ALIGNMENT
  - BENEFIT: CLOSER SPACED RUNWAYS FOR SIMULTANEOUS APPROACHES ALLOWING INCREASED CAPACITY FOR GIVEN REAL ESTATE
  - TARGET: RUNWAY SEPARATION OF 2500 FEET

- DISPLAY OF FLIGHT SITUATION ADEQUATE FOR MONITORING ADVANCED PROFILES AND TRAFFIC SITUATIONS, AND FOR PILOT INTERCEDANCE IN CONTINGENCIES
  - BENEFIT: READY PILOT ACCEPTANCE OF ADVANCED PROFILES AND CLOSE TRAFFIC SPACING
  - TARGET: PILOT ABILITY TO FLY ADVANCED PROFILES MANUALLY (AUGMENTED CONTROL MODES)

OBJECTIVE:

II. IMPROVE APPROACH AND LANDING CAPABILITY IN ADVERSE WEATHER

HOW ACHIEVE:

- AUTO CONTROL FOR PRECISION, SEQUENCED, CLOSE-IN CURVED, DECELERATING APPROACHES THROUGH LANDING AND TURNOFF
  - BENEFIT: INCREASED AIRPORT CAPACITY INDEPENDENT OF WEATHER
  - TARGETS: $\leq$ 1 1/2 MILE FINAL, 40 SECONDS SPACING AT THRESHOLD, 25 SECONDS RUNWAY OCCUPANCY

- IMPROVED AUTO CONTROL IN WINDSHEAR
  - BENEFIT: SAFETY
  - TARGET: SAME TOUCHDOWN DISPERSION AS NO WIND, ORDER OF $\pm$ 100 FEET

- DISPLAYS FOR PILOT MONITORING OF PROFILES, TRAFFIC, INSTANTANEOUS FLIGHT PATH AND THRUST COMMAND FOR WIND SHEAR, AND FOR INTERCEDENCE BY THE PILOT IF REQUIRED THROUGH LANDING AND TURNOFF
  - BENEFIT: SAFETY AND CONTINGENCY BACK-UP FOR AUTO CONTROL
  - TARGETS: MINIMIZE NEED FOR GO-AROUNDS, TRADE-OFF WITH AUTO REDUNDANCY REQUIREMENTS

- FLIGHT DECK IMPROVEMENT FOR MORE EFFICIENT UTILIZATION OF CREW AND REDUCTION OF HUMAN ERRORS
  - BENEFIT: SAFETY AND OVERALL REDUCTION IN PILOT WORKLOAD AND DIVERSIONS OF ATTENTION

- IMPROVED CWS MODES FOR PILOT CONTROL
  - BENEFIT: IMPROVED CONTROL ACCURACY, REDUCTION IN WORKLOAD AND BETTER MANAGEMENT PERFORMANCE BY PILOT

3JECTIVE:

III. REDUCE NOISE IMPACT THROUGH OPERATING PROCEDURES

HOW ACHIEVE:

- CIRCUMVENT NOISE SENSITIVE AREAS THROUGH PRECISION CURVED PATH CAPABILITY
- EXPLORE PRACTICABILITY OF STEEPER APPROACH AND DECELERATING TECHNIQUES FOR NOISE REDUCTION
  - TARGET: DETERMINE ACHIEVABLE NOISE REDUCTIONS THROUGH SUCH PROCEDURES
- DISPLAYS TO PROVIDE ORIENTATION, PRECISION PATH INFORMATION, THRUST MANAGEMENT INFORMATION FOR PILOT MONITORING OR CONTROL

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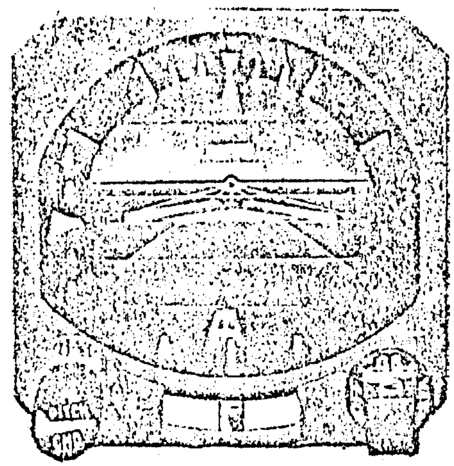
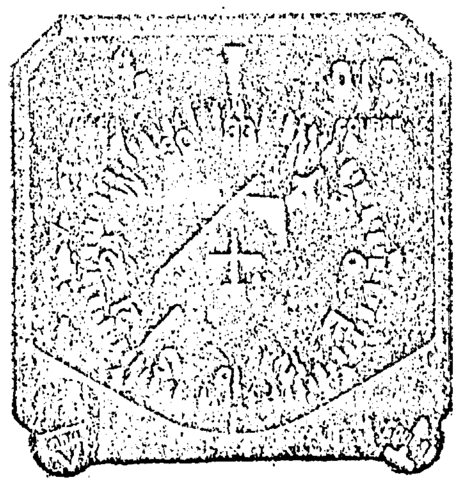
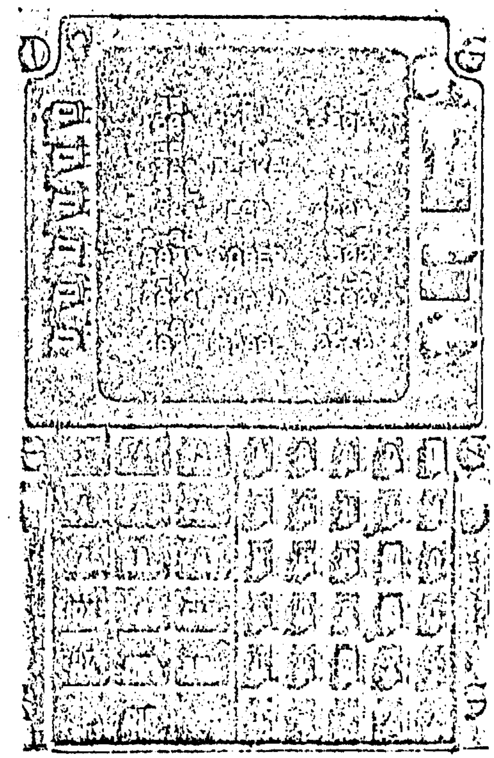
# APPENDIX K

## R-NAV COMPARISON SUMMARY

TYPICAL PILOT INTERFACE WITH A CURRENT GENERATION AREA NAVIGATION SYSTEM

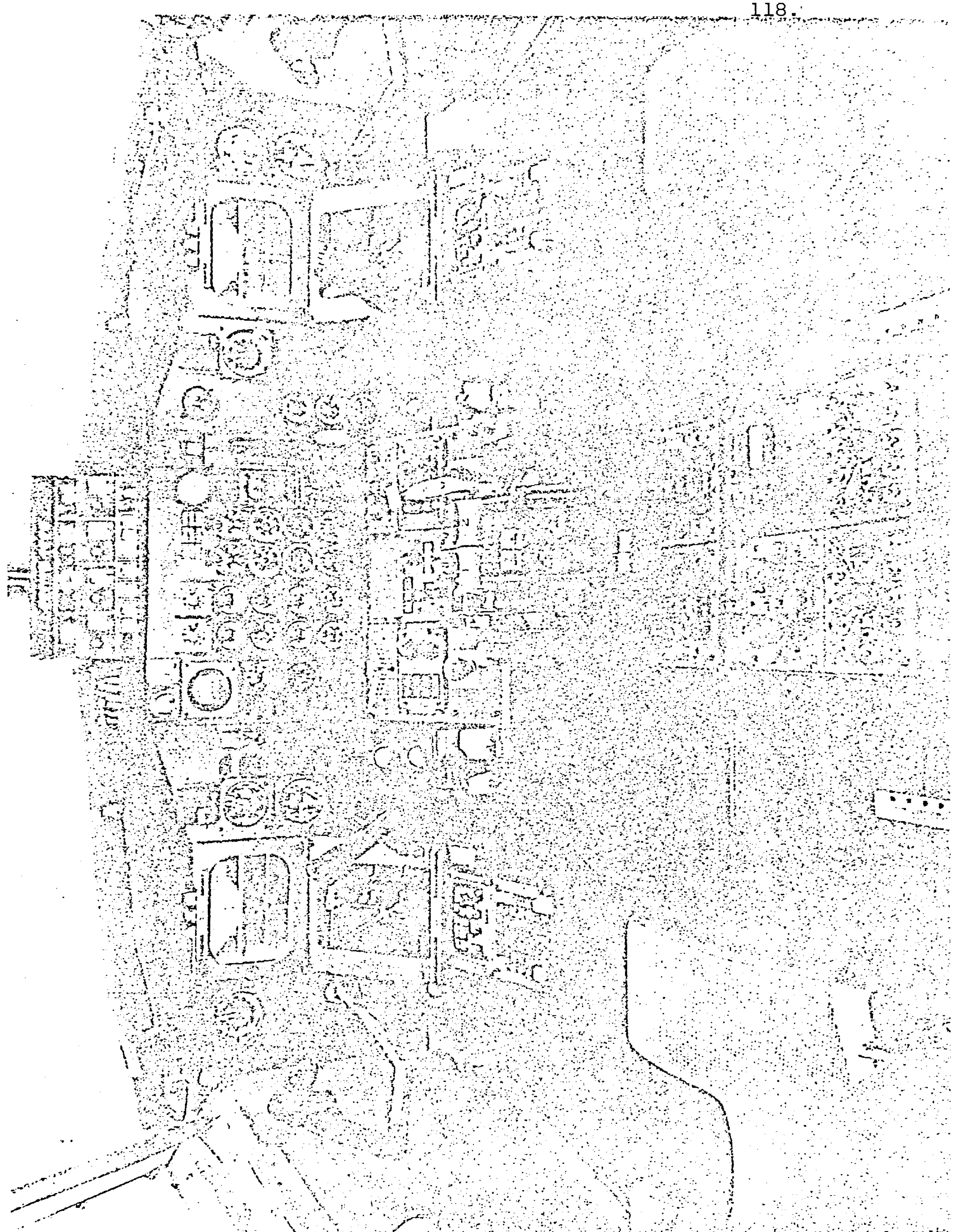






## FUNCTIONAL CAPABILITY

- 4-D NAVIGATION
- ALPHA NUMERIC READOUT WITH CATHODE RAY TUBE DISPLAYS
- NAVIGATION AND ELEMENTS OF SYSTEM INTEGRATED WITH FLIGHT CONTROLS AND DISPLAYS
- OPERATION FLEXIBLE FOR RESEARCH PURPOSES



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# APPENDIX L

W I L L I A M   T .   B U N D I C K

## SENSOR CAPABILITIES

| | |
|---|---|
| CONTRACT: | NAS1-13489 |
| SUBJECT: | ANALYTICAL EVALUATION OF ILM SENSORS |
| CONTRACTOR: | HONEYWELL |
| FINAL REPORT: | NASA-CR-132687, VOLS. 1 AND 2, SEPTEMBER 1975 |
| | NASA-CR-144902, SUPPLEMENT, OCTOBER 1975 |

## SENSOR EVALUATION CRITERIA

- °BASIC - PROVIDE INFORMATION TO ALLOW DETERMINATION OF A/C POSITION WITH RESPECT TO THE RUNWAY DOWN TO A WHEEL ALTITUDE OF 12 FT WITH ACCURACY OF THE MLS
- °CASE I - EXTEND BASIC REQUIREMENTS THROUGH TOUCHDOWN AND ROLLOUT
- °CASE II - ADD DETECTION OF OBSTACLES ON THE RUNWAY
- °CASE III - ACCOMPLISH ALL OF ABOVE THROUGH USE OF A REAL WORLD PERSPECTIVE IMAGE OF THE RUNWAY AND ITS SURROUNDINGS

# SENSOR OPERATING ENVIRONMENT

## AIRCRAFT

| | |
|---|---|
| ROLL | ±30° |
| PITCH | -3° TO +10° |
| CRAB | 20° |

## APPROACH PATH COVERAGE

| | |
|---|---|
| MAXIMUM RANGE | 8 NMI |
| AZIMUTH | ±60° |
| GLIDESLOPE | 1° TO 6° |
| CURVED PATHS | |

## WEATHER

| | |
|---|---|
| RAINFALL RATE | 16 MM/HR |
| RVR | 0 FT |
| SNOWFALL RATE | 5 MM/HR |

## TV RESULTS

| WEATHER | RVR (FT) | MAX. DET. RANGE (N. MI.) | | |
|---|---|---|---|---|
| | | R/W | R/W LIGHTS | OBSTACLE |
| CAT I | 2400 | .2 - .5 | .3 - 1.1 | .2 - .3 |
| CAT II | 1600 | .16 - .4 | .3 - .8 | |
| 5 MM/HR RAIN | 3040 | .3 - .7 | .4 - 1.4 | .2 - .4 |
| 5 MM/HR SNOW | 760 | <.5 | <.5 | |

## FLIR RESULTS

| WEATHER | RVR (FT) | MAX. DET. RANGE (N. MI.) R/W | OBSTACLE |
|---|---|---|---|
| CAT I | 2400 | .8 - 1.6 | <.2 |
| CAT II | 1600 | .5 - 1.1 | |
| 5 MM/HR RAIN | 3040 | 1.1 - 2.2 | <.2 |
| 5 MM/HR SNOW | 760 | <.5 | |
| CLEAR | | 8* | |

* 2 N. MI. FOR RECOGNITION

## IMAGING RADAR RESULTS

| WEATHER | RUNWAY DETECTION RANGE $K_A$-BAND | RUNWAY DETECTION RANGE X-BAND |
|---|---|---|
| 16 MM/HR RAIN | 0.5 - 0.8 | 1 - 2.2 |
| 5 MM/HR RAIN | 1.1 - 2.7 | |
| 9 MM/HR SNOW | | 1.1 - 2.9 |
| CLEAR | 1.6 - 4.3 | 2 - |

## IMAGING SENSOR RESULTS

| SENSOR | SPATIAL RESOLUTION | CAT. II MAX. RANGE R/W DET. | PROBLEMS |
|---|---|---|---|
| IMAGING RADAR ($K_A$-BAND) | .3° - .7° x 20′ - 100′ | .5 - .8 N. MI.* | RESOLUTION, WEATHER |
| BISTATIC IMAGING RADAR (X-BAND) | .25° - .5° x 20′ - 100′ | 1 - 2.2 N. MI.* | RESOLUTION, COMPLEXITY |
| TV | .03° - .06° x .03° - .06° | .16 - .4 N. MI. | WEATHER |
| FLIR | .06° x .06° | .5 - 1.1 N. MI. | WEATHER |
| MICROWAVE RADIOMETER | .3° - .7° x .3° - .7° | | RESOLUTION, WEATHER |

*16 MM/HR RAIN

## NON-IMAGING SENSOR RESULTS

| SENSOR | ACCURACY AZ/HOR | ACCURACY EL/VERT | MAX. RANGE | PROBLEMS |
|---|---|---|---|---|
| MLS | .032° | .032° | >20 N. MI. | NOT PHENOMENALLY REDUNDANT |
| MULTILATERATION | 15 FT | 60-100 FT | 20 N. MI. | ALTITUDE, LINE-OF-SIGHT, DATA LINK |
| TRIANGULATION RADAR | .27°-.63° | .09°-.12° | >5 N. MI. | |
| INTERFEROMETER | .14°-.74° | .14°-.43° | | MULTIPATH, DATA LINK |
| CIRCULAR SYN. APERTURE | .1°-1° | .1°-1° | | DATA PROCESSING |
| NUCLEAR | 1 FT? | 1 FT? | 1.5 N. MI.? | SAFETY, RANGE |

Langley

## CONCLUSIONS

- THE CAPABILITIES OF A REAL WORLD PERSPECTIVE IMAGING SENSOR CANNOT BE ACCURATELY DETERMINED VIA ANALYSIS
- IMAGING RADARS MEET TO SOME DEGREE ALL OF THE ASSUMED FUNCTIONAL REQUIREMENTS
- MULTILATERATION, REDUNDANT MLS, COMPLEX INTERFEROMETRY, AND SYNTHETIC CIRCULAR APERTURE PROVIDE BETTER APPROACH COVERAGE, WEATHER PENETRATION, AND POSITION ACCURACY THAN IMAGING RADAR, BUT DO NOT PROVIDE OBSTACLE DETECTION OR REAL WORLD IMAGE

## APPENDIX M

JAMES E. STITT

## RECOMMENDATIONS OF AERONAUTICAL OPERATING

## SYSTEMS PANEL - OCTOBER 28-29, 1975

- THAT NASA STRENGTHENS AND MAINTAINS ITS COORDINATION WITH FAA TO ENSURE THAT THE TCV PROGRAM WILL RELATE TO AND PROVIDE SUPPORTING INFORMATION FOR ATC SYSTEM EVOLUTION

- THAT THE NEAR-, MID-, AND LONG-TERM OBJECTIVES OF THE TCV PROGRAM BE MORE CLEARLY DEFINED IN THE CONTEXT OF CURRENT AS WELL AS FUTURE AIRCRAFT SYSTEMS CAPABILITIES AND THE RESEARCH GOALS OF THE TCV PROGRAM

- THAT THE POTENTIAL IMPACT OF "WEATHER MODIFICATION" ON THE REQUIREMENTS FOR LANDING AND POST LANDING SYSTEMS BE FULLY TAKEN INTO ACCOUNT, INCLUDING A QUANTITATIVE DETERMINATION OF THE WEATHER PENETRATING POTENTIAL OF AIRBORNE SYSTEM TECHNOLOGIES (SUCH AS IR AND LASERS)

## RECOMMENDATION OF RTAC PANEL ON TCV

- EXPLORE AND DEFINE THE PILOT INTERFACE WITH THE PRESENT AND FUTURE ATC SYSTEM
- EMPHASIZE BASIC RESEARCH WORK ON THE HUMAN FACTORS ELEMENTS IN CONDUCTING COMPLEX APPROACH AND LANDING - (SEE ATTACHMENT)
- CLEARLY DEFINE PRESENT SYSTEM CAPABILITIES AND SHOW THE IMPROVEMENTS THAT THE TCV PROGRAM IS PROJECTED TO ACHIEVE
- THERE SHOULD BE FAA FLIGHT STANDARDS AND "SYSTEMS ENGINEERING" PANEL MEMBERS

## NASA RESPONSE TO AERONAUTICAL

## OPERATING SYSTEMS PANEL RECOMMENDATIONS

- STEPS TAKEN TO MAINTAIN COORDINATION WITH FAA
  - AT LEAST EIGHT MEETINGS WITH FAA (OCTOBER 1975 THROUGH JUNE 1976)
  - COOPERATIVE PROGRAM WITH FAA TO ACCOMPLISH ICAO DEMONSTRATION AND ACQUIRE MLS PERFORMANCE DATA
  - PLANNED FLIGHTS JULY 1976 TO OBTAIN PERFORMANCE DATA ON THINNED ARRAY AND COUPLED-LANDINGS USING BODY MOUNTED ACCELEROMETERS ONLY
  - ACQUISITION AND EVALUATION OF A PHASE III - WIDE APERTURE MLS SYSTEM FOR INSTALLATION AT WALLOPS INITIATED
- STEPS TAKEN TO REVISE OBJECTIVES OF TCV PROGRAM
  - DEFINED NEW OBJECTIVES REFLECTING RECOMMENDATIONS ON HUMAN FACTORS, ATC-AIRCRAFT SYSTEMS RELATIONSHIPS, ETC., UNDER REVIEW BY RTAC PANEL ON TCV

- RECOMMENDATION ON POTENTIAL IMPACT OF "WEATHER MODIFICATION" ON REQUIREMENTS FOR LANDING AND POST LANDING SYSTEMS
  - REFLECTED IN REVISED GOALS - DETAIL PROGRAM PLANNING UNDERWAY
  - INITIATED PLANNING WITH NASA HEADQUARTERS AND AMES TO UNDERTAKE SPECIFIC EFFORTS ON HUMAN FACTORS AS RELATED TO WEATHER MODIFICATIONS
  - REVIEWING COMPLETED STUDY ON WEATHER PENETRATING POTENTIAL OF AIRBORNE SENSORS FOR TCV RTAC PANEL AND REQUESTING PANEL RECOMMENDATIONS ON FUTURE EFFORTS

## NASA RESPONSE TO RECOMMENDATIONS

## OF RTAC PANEL ON TCV

- REVISED TCV OBJECTIVES TO REFLECT "PILOT INTERFACE WITH THE PRESENT AND FUTURE ATC SYSTEM" AS MAJOR OBJECTIVE. PROGRAM PLANNING UNDERWAY.

- "HUMAN FACTORS ELEMENTS" REFLECTED AS MAJOR OBJECTIVE IN REVISED OBJECTIVES. HAVE INITIATED THE DEFINITION OF SPECIFIC TASKS WITH AMES AND HAVE ASSIGNED ADDITIONAL PERSONNEL IN THIS AREA AT LRC.

- INITIAL PRESENTATION OF EFFORTS TO "DEFINE PRESENT SYSTEM CAPABILITIES AND COMPARE IMPROVEMENTS THAT TCV PROGRAM IS PROJECTED TO ACHIEVE" SCHEDULED FOR RTAC-PANEL MEETING. NEED DISCUSSION AND FURTHER CLARIFICATION OF THIS RECOMMENDATION.

APPENDIX N

# AMES HUMAN FACTORS PROGRAM

## BASIC RESEARCH STUDIES

### 1. SENSORY MECHANISMS

#### a. VISUAL ACCOMMODATION EFFECTS ON DISPLAY PERCEPTION

Roscoe, Stanley, N. "Ground-referenced visual orientation: judgments of size and distance." Technical Report, Aviation Research Laboratory, Institute of Aviation, University of Illinois at Urbana-Champaign. April, 1975.

Roscoe, Stanley N. "Ground-referenced visual orientation in flight control tasks." Technical Proposal TP75-100, HAC ref. no. 75-22-10029/D5850-001, Hughes Aircraft Company, Aerospace Group, Culver City, California. June, 1975.

#### b. PERIPHERAL VISUAL CUE PERCEPTION AND UTILIZATION

Haines, R. "Peripheral Visual Response Time and Visual Display Layout." (Available from author).

Haines, R. "Effect of Passive 70 Degree Head-Up Tilt on Peripheral Visual Response Time." J. of Applied Physiology, Vol. 34, No. 3, March, 1973.

Haines, R., Dawson, L.M., Galvan, T. and Reid, L.M. "Response Time to Colored Stimuli in the Full Visual Field." NASA TN D-7927, March, 1975.

### 2. INFORMATION PROCESSING

#### a. VISUAL PERCEPTION DISTORTIONS WITH ARTIFICIAL SCENES

Palmer, E. and Petitt, J. "Visual Space Perception on a Computer Graphics Night Visual Attachment." (AIAA Paper available from author).

Palmer, E. and Petitt, J. "Difference Thresholds for Judgments of Sink Rate During the Flare." (AIAA Paper available from author).

b. SIGNAL DETECTION FOR LANDING DECISION EVALUATION

Tanner, T. A. "Signal Recognition as an Analog to Decision-making in Limited Visibility Landing." Applications of Research on Human Decision-making, Symposium held at Ames Research Center, California, January 31 - February 2, 1968. NASA SP-209.

c. DYNAMIC DECISIONS WITH CHANGING SIGNAL-TO-NOISE RATIO

Curry, R. and Gai, E. "Decision Goals in Signal Detection and Recognition." Presented at the Tenth Annual Conference on Manual Control, Wright-Patterson AFB, April 9-11, 1974.

Curry, R., Kleinman, D. and Hoffman, W., "A Model for Simultaneous Monitoring and Control." Proceedings of the Eleventh Annual Conference on Manual Control, NASA-Ames Research Center, Moffett Field, California, NASA TMX 62,464, May 1975.

Curry, R., Lauber, J. and Billings, C., "The Simulation of Stress During Low Visibility Approaches." Proceedings of the Eleventh Annual Conference on Manual Control, NASA-Ames Research Center, Moffett Field, California, NASA TMX 62,464, May 1975.

Curry, R. and Ephrath, A., "Monitoring and Control of Unreliable Systems." Presented at the International Symposium on Monitoring Behavior and Supervisory Control, Berchtesgaden, W. Germany, March 1976.

Curry, R.E. and Govindaraj, T., "The Psychophysics of Random Processes." Twelfth Annual Conference on Manual Control, May 25-27, 1976, University of Illinois (Proceedings in process as NASA SP).

Ephrath, A., "Detection of System Failures in Multi-Axes Tasks." Proceedings of the Eleventh Annual Conference on Manual Control, NASA-Ames Research Center, Moffett Field, California, NASA TMX 62,464, May 1975.

Ephrath, A., "Pilot Performance in Zero-Visibility Precision Approach." NASA CR-137759, October 1975.

Ephrath, A.R., "The Effects of Control Modes on Fault Detection Performance at a Constant Workload." Twelfth Annual Conference on Manual Control, May 25-27, 1976, University of Illinois (Proceedings in process as NASA SP).

Eprath, A.R., "A Novel Approach to the Cross-Adaptive Auxiliary Task." Twelfth Annual Conference on Manual Control, May 25-27, 1976, University of Illinois (Proceedings in process as NASA SP).

Gai, E. and Curry, R., "Failure Detection by Pilots During Automatic Landings: Models and Experiments." Proceedings of the Eleventh Annual Conference on Manual Control, NASA-Ames Research Center, Moffett Field, California, NASA TMX 62,464, May 1975.

Gai, E., "Psychophysical Models for Signal Detection with Time-Varying Uncertainty." NASA CR-137734, September 1975.

## 3. COMMUNICATIONS AND LINGUISTICS

### a. SUPERVISORY CONTROL OF AUTOMATIC SYSTEMS

Sheridan, T.B., "Review of International Symposium on Monitoring Behavior and Supervisory Control (Berchtesgaden, F.R., Germany, March 1976), Twelfth Annual Conference on Manual Control, May 25-27, 1976, University of Illinois (Proceedings in process as NASA SP).

Sheridan, T.B. and Tulga, M.K., "Modeling Task Allocation in Flight Management: Preliminary Developments." Twelfth Annual Conference on Manual Control, May 25-27, 1976, University of Illinois (Proceedings in process as NASA SP).

### b. PILOT INTERACTION WITH AUTOMATED AIRBORNE DECISION-MAKING SYSTEMS

Enstrom, K.D. and Rouse, W.B., "Telling a Computer How a Human Has Allocated His Attention Between Control and Monitoring Tasks." Twelfth Annual Conference on Manual Control, May 25-27, 1976, University of Illinois (Proceedings in process as NASA SP).

Rouse, W.B., Chu, Y-Y. and Walden, R.S., "An Experimental Situation for Study of Pilot Interaction with Automated Airborne Decision-Making Systems." Twelfth Annual Conference on Manual Control, May 25-27, 1976, University of Illinois (Proceedings in process as NASA SP).

Rouse, W.B. and Greenstein, J.S., "An Experimental Situation for Study of Human Decision-Making in Multi-Process Monitoring." Twelfth Annual Conference on Manual Control, May 25-27, 1976, University of Illinois (Proceedings in process as NASA SP).

# 4. STRESS AND WORKLOAD

## a. TIME PERCEPTION AND WORKLOAD

Hart, S. and Huff, E., "The Influence of Distraction on the Perception of Time." Western Psychological Association, Sacramento, California, April 1975.

Hart, S., "Time Estimation of A Secondary Task." Proceedings of the Eleventh Annual Conference on Manual Control, NASA-Ames Research Center, Moffett Field, California, NASA TMX 62,474, May 1975.

Hart, S.G. and Mc Pherson, D., "Airline Pilot Time Estimation During Concurrent Activity Including Simulated Flight." Preprints of 1976 Annual Scientific Meeting, Washington, D.C.: Aerospace Medical Association, 1976.

# AMES HUMAN FACTORS PROGRAM

## FUNDAMENTAL MISSION STUDIES BY SIMULATION OR FLIGHT

### 1. COORDINATED COCKPIT DISPLAYS

Baty, D., Wempe, T., and Huff, E. "A Study on Aircraft Map Display Location and Orientation." Presented at the Ninth Annual Conference on Manual Control, M.I.T., May 23-25, 1973.

Baty, D., "An Evaluation of a Predictor Used With Two Different Aircraft Map Display Orientations." Presented at the Tenth Annual Conference on Manual Control, Wright-Patterson AFB, April 9-11, 1974.

Baty, D.L., "Introduction to a Coordianted Cockpit Display (CCD) Concept." Twelfth Annual Conference on Manual Control, University of Illinois, May 25-27, 1976 (Proceedings in process as NASA SP).

Kreifeldt, J. and Wempe, T., "Pilot Performance During a Simulated Standard Instrument Procedure Turn With and Without a Predictor Display." Presented at the Ninth Annual Conference on Manual Control, M.I.T., May 23-25, 1973.

Murphy, M., McGee, L., Palmer, E., Paulk, C. and Wempe, T., "Simulator Evaluation of Three Situation and Guidance Displays for V/STOL Zero-Zero Landings." Presented at the Tenth Annual Conference on Manual Control, Wright-Patterson AFB, April 9-11, 1974.

### 2. WARNING SYSTEMS

Simpson, C. and Williams, D., "Human Factors Research Problems in Voice Warning System Design." Proceedings of the Eleventh Annual Conference on Manual Control, NASA-Ames Research Center, Moffett Field, Calif., NASA TMX 62,474, May 1975.

Wempe, T., "Flight Management - Pilot Procedures and System Interfaces for The 1980-1990's." AIAA Paper No. 74-1297, Arlington, Texas, 1974.

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## 3. DISTRIBUTED AIR TRAFFIC CONTROL

Kreifeldt, J. and Wempe, T., "Future Concepts in Terminal Air Traffic Management." Proceedings of the Tenth Annual Conference on Manual Control, Wright-Patterson AFB, April 1974.

Kreifeldt, J. and Wempe, T., "Human Decision Making in Future ATC Systems." Proceedings of the International onference on Systems, Man and Cybernetics, IEEE, Dallas, Texas, October 1974.

Kreifeldt, J., Pardo, B., Wempe, T. and Huff, E., "Verbal Workload in Distributed Air Traffic Management." Proceedings of the Eleventh Annual Conference on Manual Control, NASA-Ames Research Center, Moffett Field, California, NASA TMX 62,474, May 1975.

Kreifeldt, J., Parkin, L., Wempe, T. and Huff, E., "Subjective Evaluation with FAA Criteria - A Multidimensional Scaling Approach." Proceedings of the Eleventh Annual Conference on Manual Control, NASA-Ames Research Center, Moffett Field, California, NASA TMX 62,474, May 1975.

Kreifeldt, J.G. and Wempe, T.E., "Implications of a Mixture of Aircraft With and Without Traffic Situation Displays for Air Traffic Management." Twelfth Annual Conference on Manual Control, University of Illinois, May 25-27, 1976 (Proceedings in process as NASA SP).

## 4. TRAFFIC SITUATION DISPLAY AND 4D RNAV IN TERMINAL AREA MANEUVERS

Many past reports -- research ongoing.

# AMES HUMAN FACTORS PROGRAM

## PRIOR HUD STUDIES

1.

Bourquin, K., Palmer, E., Cooper, G. and Gerdes, R., "Initial Flight and Simulator Evaluation of a Head-Up Display for Standard and Noise Abatement Visual Approaches." NASA TMX-62,187, 1972.

Cronn, F. and Palmer, E., "Comparison of Two Head-Up Displays in Simulated Standard and Noise Abatement Night Visual Approaches." NASA TMX-3264, July 1975.

Dwyer, J. and Palmer, E., "A Comparison of Three Methods of Presenting Flight Vector Information in a Head-Up Display During Simulated STOL Approaches." NASA TMX-3273, July 1975.

Palmer, E., "Night Visual Approaches - Pilot Performance With and Without a Head-Up Display." NASA TMX-62,188, 1972.

Palmer, E. and Cronn, F., "Head-Up Displays for STOL Visual Approaches." Presented at the STOL Technology Conference, Ames Research Center, Moffett Field, California, October 1972.

# APPENDIX O

DR. THOMAS M. WALSH

TERMINAL CONFIGURED VEHICLE PROGRAM

PARTICIPATION IN THE U. S. MLS

DEMONSTRATION TO THE AWOP/ICAO

JULY 19, 1976

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## DEMONSTRATION GROUND RULES

- 3D AUTOMATIC CURVED, DESCENDING APPROACHES AND LANDINGS
  - (A) EXISTING NAVIGATION CONTROL LAWS USED FOR CURVED PORTIONS WITH MLS GUIDANCE SUBSTITUTED FOR INS
  - (B) EXISTING AUTOLAND SYSTEM MODIFIED TO REMOVE INS SMOOTHING, MLS DEVIATIONS SUBSTITUTED FOR ILS
- MLS USED FOR ROLLOUT GUIDANCE IF CONDITIONS ALLOW FULL STOP LANDING
- MLS USED TO EXTENT FEASIBLE FOR DISPLAYS
  - (A) HORIZONTAL SITUATION (MAP)
  - (B) CURVED TREND VECTOR
  - (C) CENTERLINE AND GLIDEPATH DEVIATIONS AND AUTOLAND BOX

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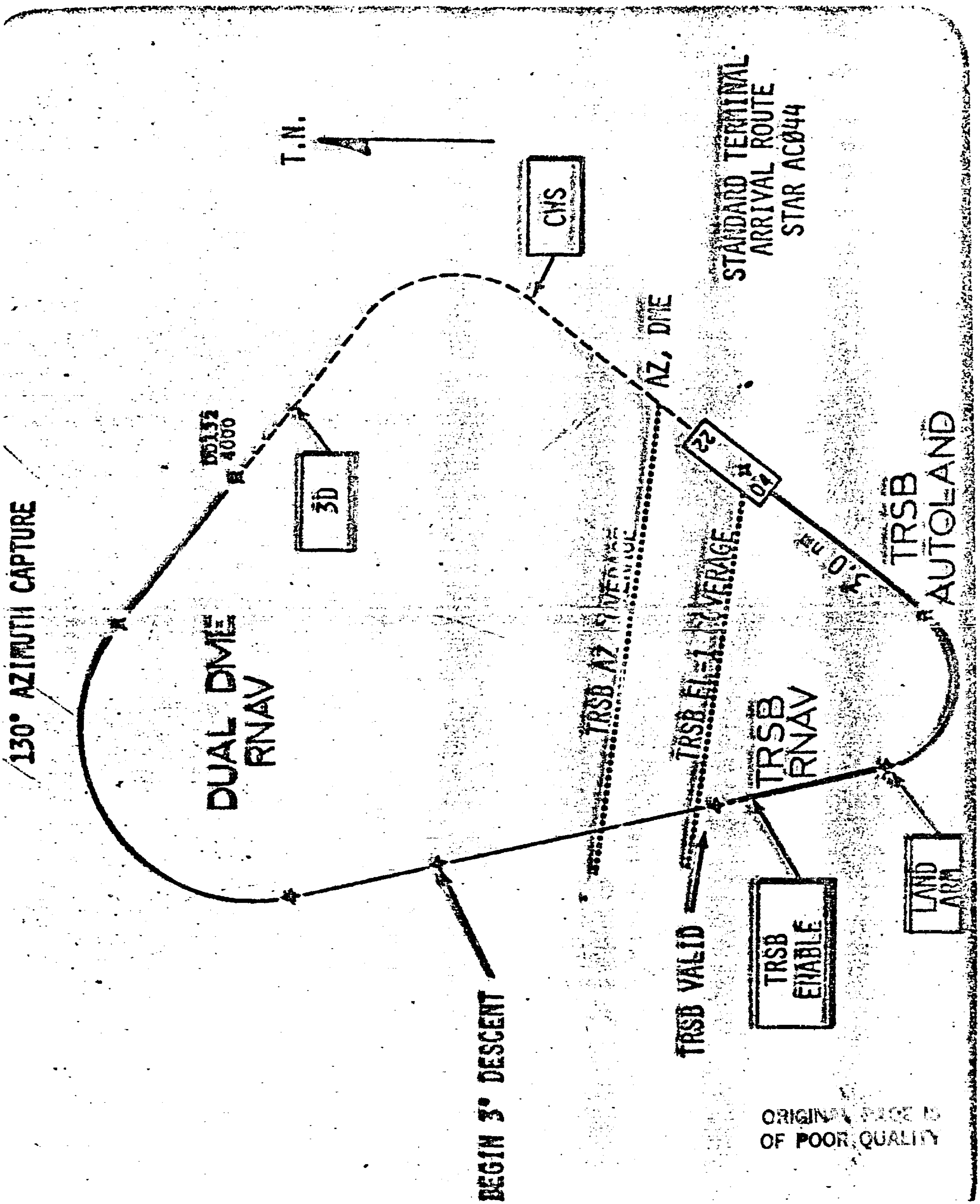


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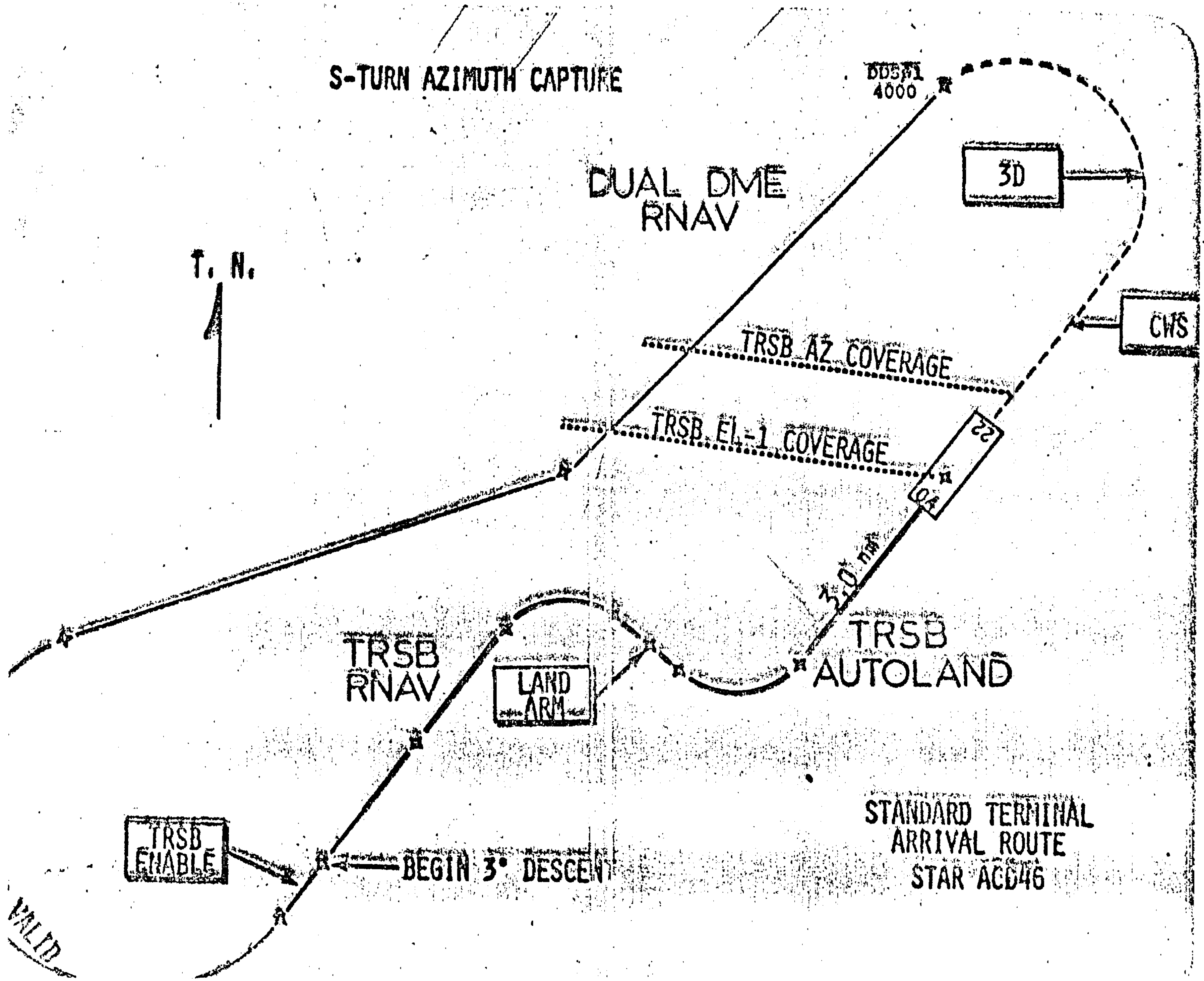
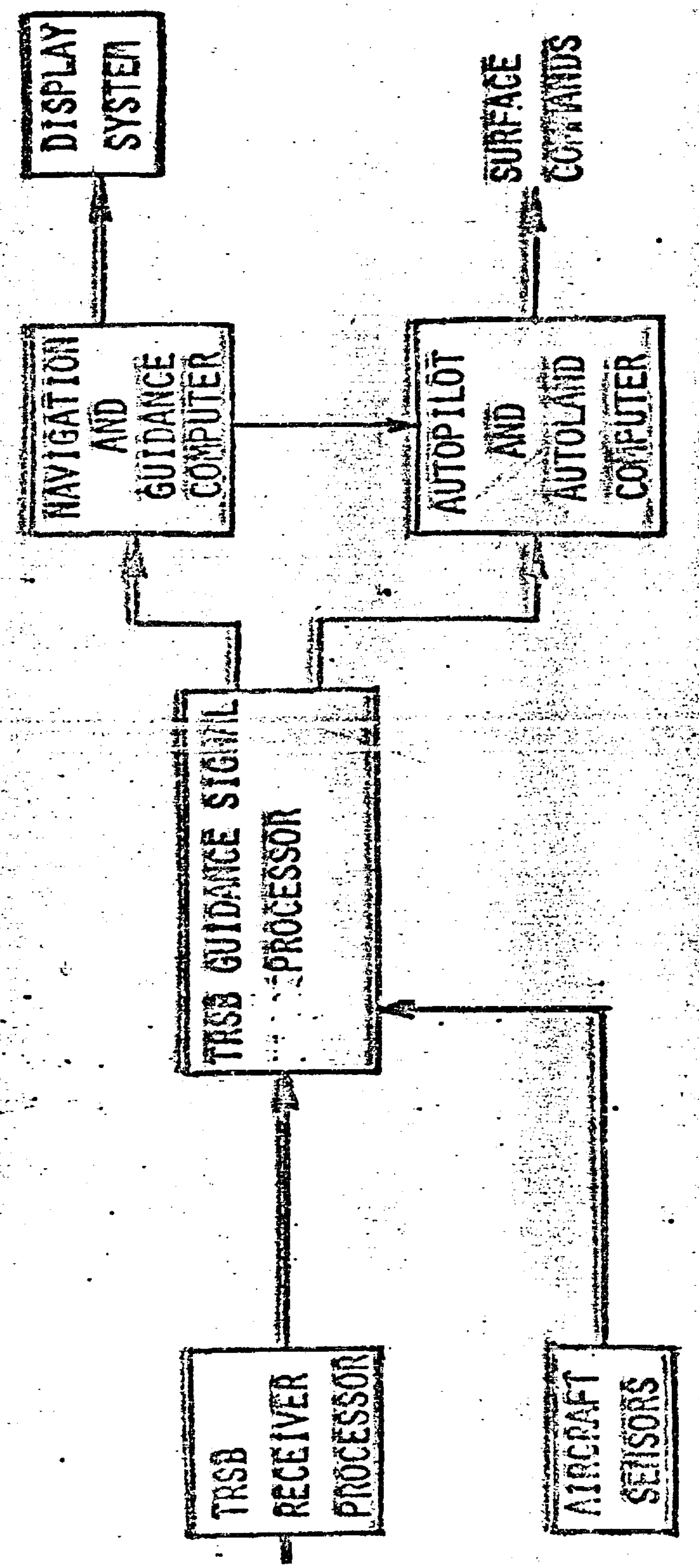

S-TURN AZIMUTH CAPTURE
DD5M1
4000
DUAL DME
RNAV
3D
T. N.
CWS
TRSB AZ COVERAGE
TRSB EL-1 COVERAGE
22
04
3.0 nm
TRSB
AUTOLAND
TRSB
RNAV
LAND
ARM
TRSB
ENABLE
BEGIN 3° DESCENT
VALID
STANDARD TERMINAL
ARRIVAL ROUTE
STAR ACD46

AUTOMATIC GUIDANCE AND CONTROL WITH TRSB MLS

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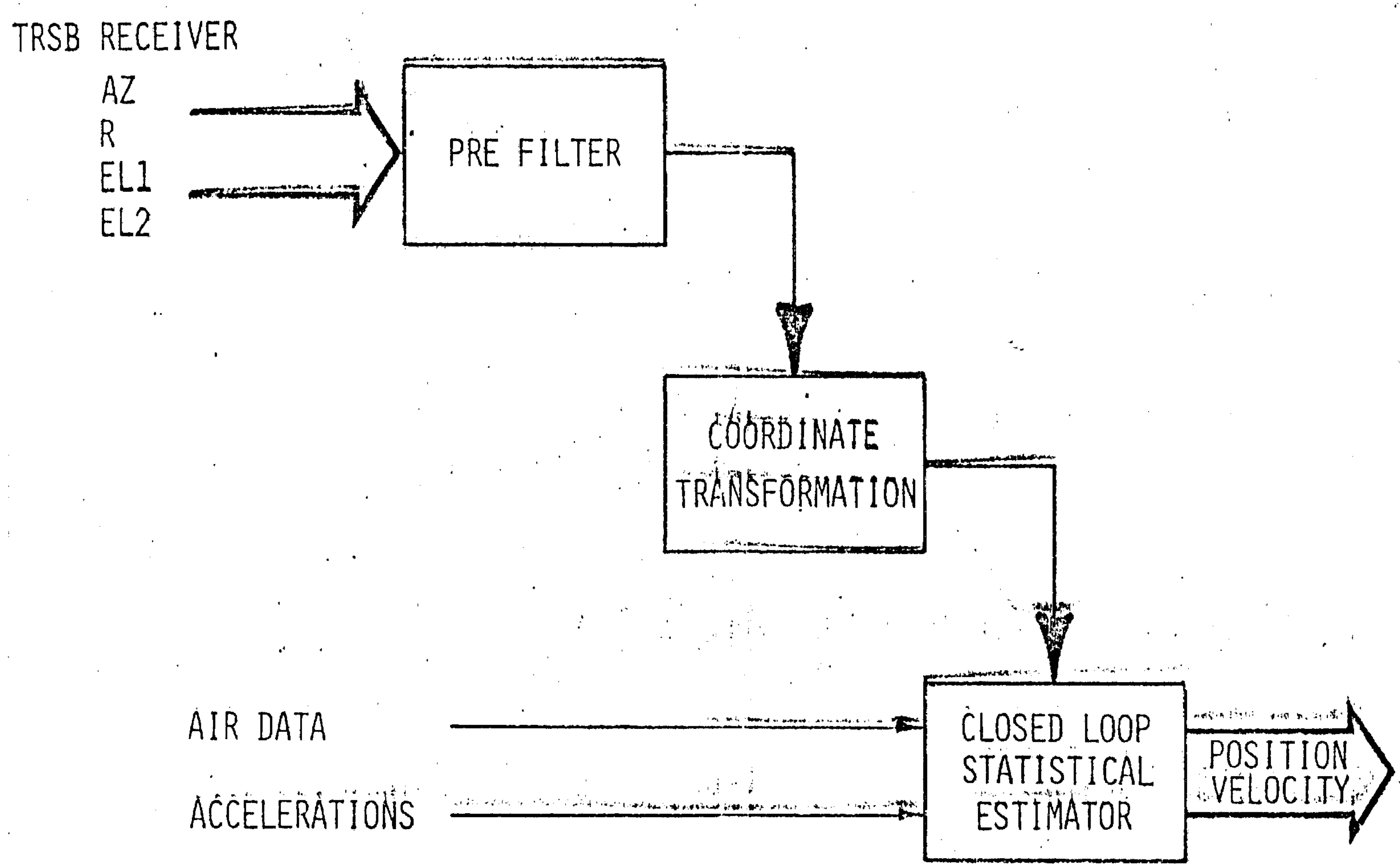
TRSB PROCESSOR DETAIL



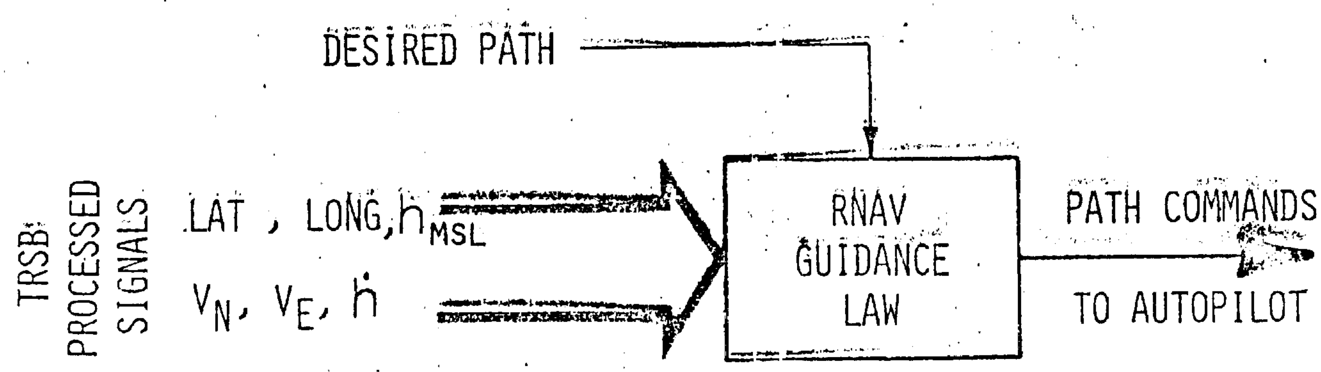
## TRSB PROCESSED SIGNAL USE FOR NAVIGATION, GUIDANCE

NAVIGATION

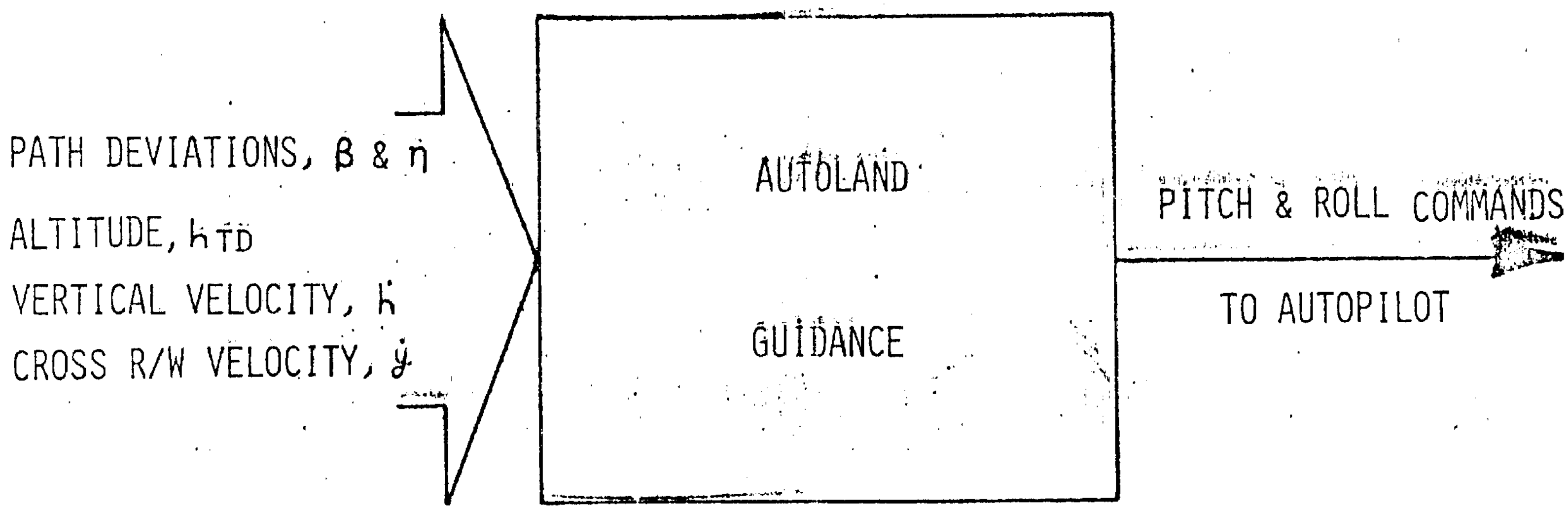
$$LAT_{TRSB} = LAT_{\substack{TRSB\\ORIGIN}} + \Delta LAT_{\substack{TRSB\\PROCESSED}}$$

$$LONG_{TRSB} = LONG_{\substack{TRSB\\ORGIN}} + \Delta LONG_{\substack{TRSB\\PROCESSED}}$$

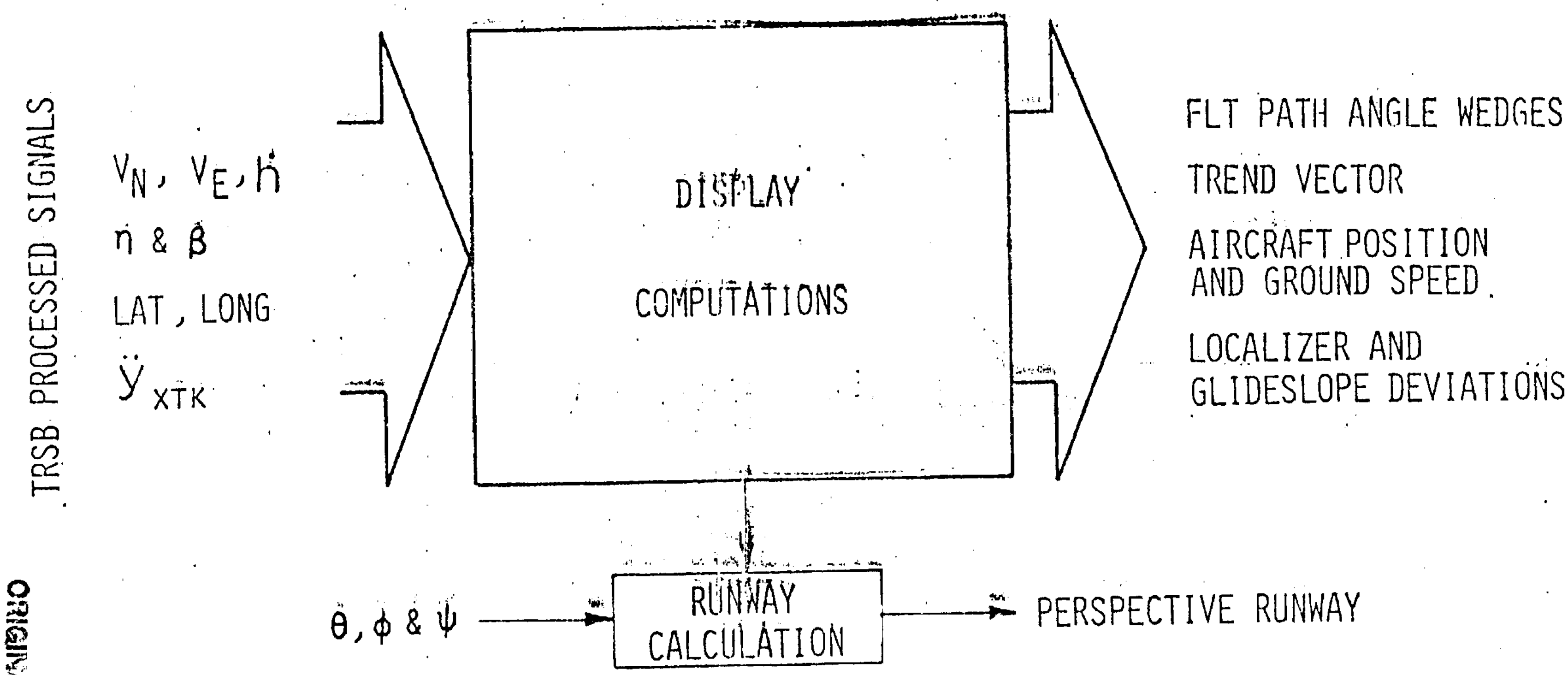
GUIDANCE



TRSB PROCESSED SIGNAL USE FOR AUTOLAND



TRSB PROCESSED SIGNAL USE FOR NAVIGATION DISPLAYS

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# DEFINITION OF NOTATION

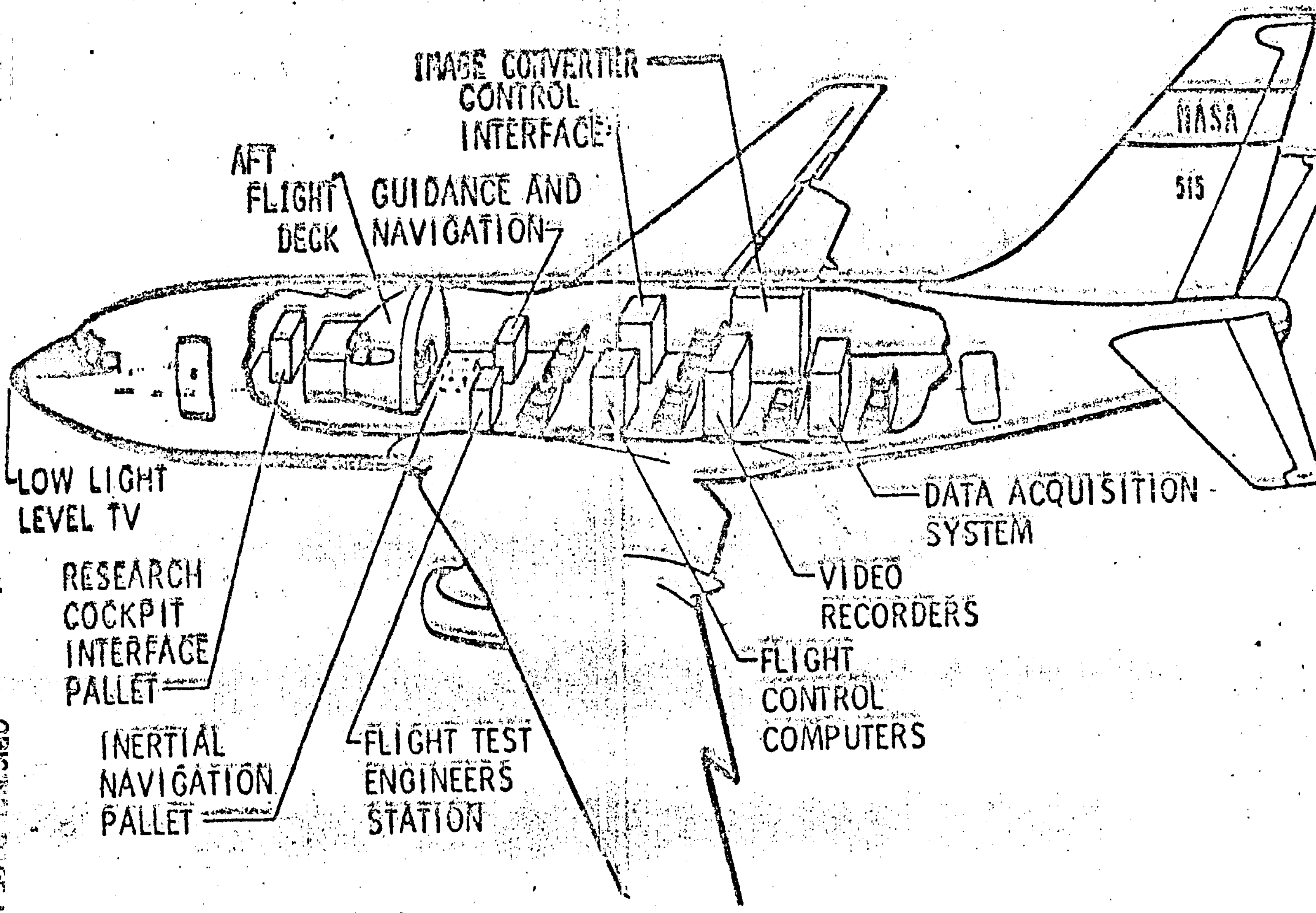
NAVIGATION AND DISPLAY VARIABLES FROM TRSB PROCESSOR

| | |
|---|---|
| LAT | LATITUDE DEVIATION FROM TRSB COORDIANTE FRAME ORIGIN |
| LONG | LONGITUDINAL DEVIATION FROM TRSB COORDINATE FRAME ORIGIN |
| $h_{MSL}$ | MEAN SEA LEVEL ALTITUDE |
| $V_N$ | - NORTH VELOCITY |
| $V_E$ | - EAST VELOCITY |
| $\dot{h}$ | - VERTICAL VELOCITY OF AIRCRAFT IN THE TRSB COORDINATE FRAME |
| $LAT_{ORG}$ | - LATITUDE OF TRSB COORDINATE FRAME ORIGIN |
| $LONG_{ORG}$ | - LONGITUDE OF TRSB COORDINATE FRAME ORIGIN |
| $\Delta$ $LAT_{TRSB}$ | - LATITUDE OF THE AIRCRAFT COMPUTED FROM TRSB |
| $\Delta$ $LONG_{TRSB}$ | - LONGITUDE OF THE AIRCRAFT COMPUTED FROM TRSB |
| $\eta$ | - LOCALIZER ANGLE DEVIATION FROM DESIRED PATH |
| $\beta$ | - GLIDESLOPE ANGLE DEVIATION FROM DESIRED PATH |
| $\ddot{y}_{XTK}$ | - CROSS-TRACK ACCELERATION |

AUTOLAND VARIABLES FROM TRSB PROCESSOR

| | |
|---|---|
| $\eta$ | - LOCALIZER ANGLE DEVIATION FROM DESIRED PATH |
| $\beta$ | - GLIDESLOPE ANGLE DEVIATION FROM DESIRED PATH |
| $h_{TD}$ | - ALTITUDE TO TOUCHDOWN RELATIVE TO GROUND ELEVATION AT THE EL1 ANTENNA |
| $\dot{h}$ | - VERTICAL VELOCITY IN TRSB COORDINATE FRAME |
| $\dot{y}$ | - CROSS-RUNWAY VELOCITY |

# RESEARCH SUPPORT FLIGHT SYSTEM INTERNAL ARRANGEMENTS

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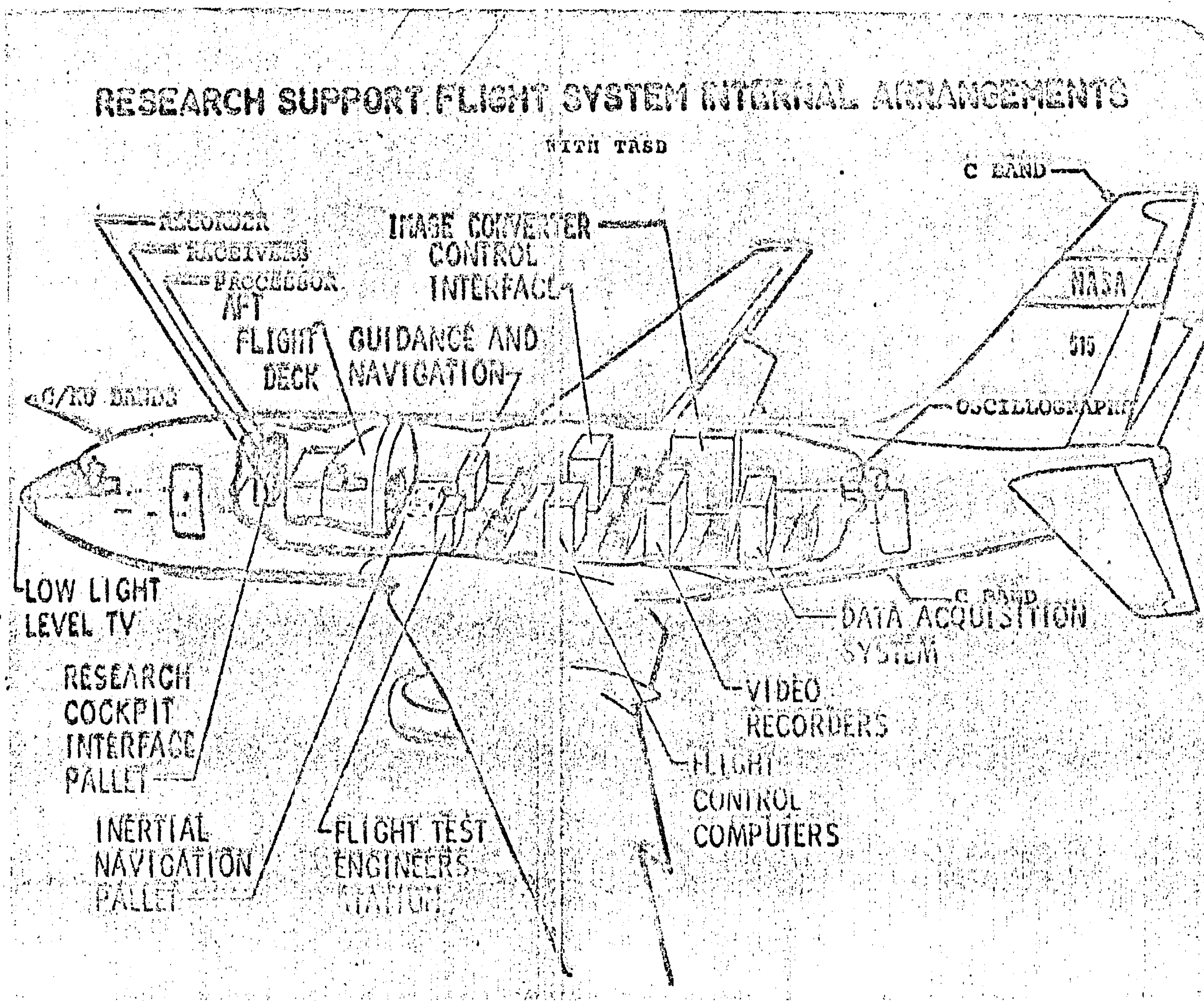


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# TRSD FLIGHTS

| | APPROACHES | | FLARES | |
|---|---|---|---|---|
| | 130° | "S" | EL2 | RADIO ALT. |
| DEVELOPMENT FLIGHTS (9/4/75-5/7/76) | 88 | 20 | 13 | 95 |
| ICAO DEMONSTRATION (5/12-13/76) | 17 | 4 | 10 | 9 |
| MEDIA, INDUSTRY & VIP DEMONSTRATION (5/18-5/20/76) | 23 | 8 | 23 | 5 |
| TOTAL | 128 | [illegible] ([illegible]) | 46 | 109 (155) |

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# TRSB FLIGHT RESULTS - DOCUMENTATION EFFORTS

FLIGHT SYSTEM DESIGN APPROACH

SIMULATION STUDIES

FLIGHT SYSTEM CONFIGURATION

FLIGHT PERFORMANCE

- PATH TRACKING
- SPEED CONTROL
- DISPLAYS EVALUATION
- WIND, SHEAR, & TURBULENCE ENVIRONMENT
- TRSB SIGNAL QUALITY
- NAVIGATION, GUIDANCE AND CONTROL SYSTEM PERFORMANCE

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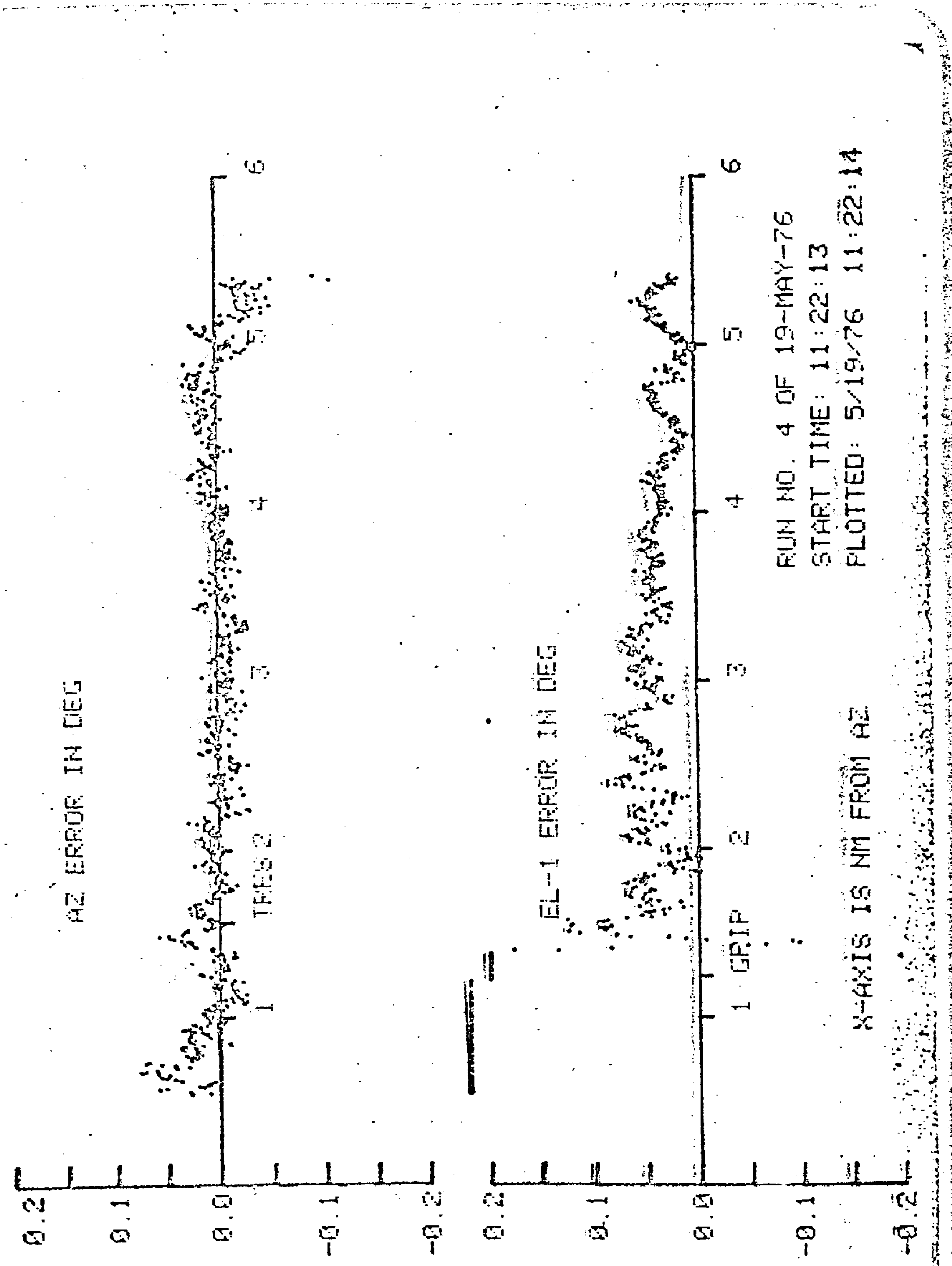


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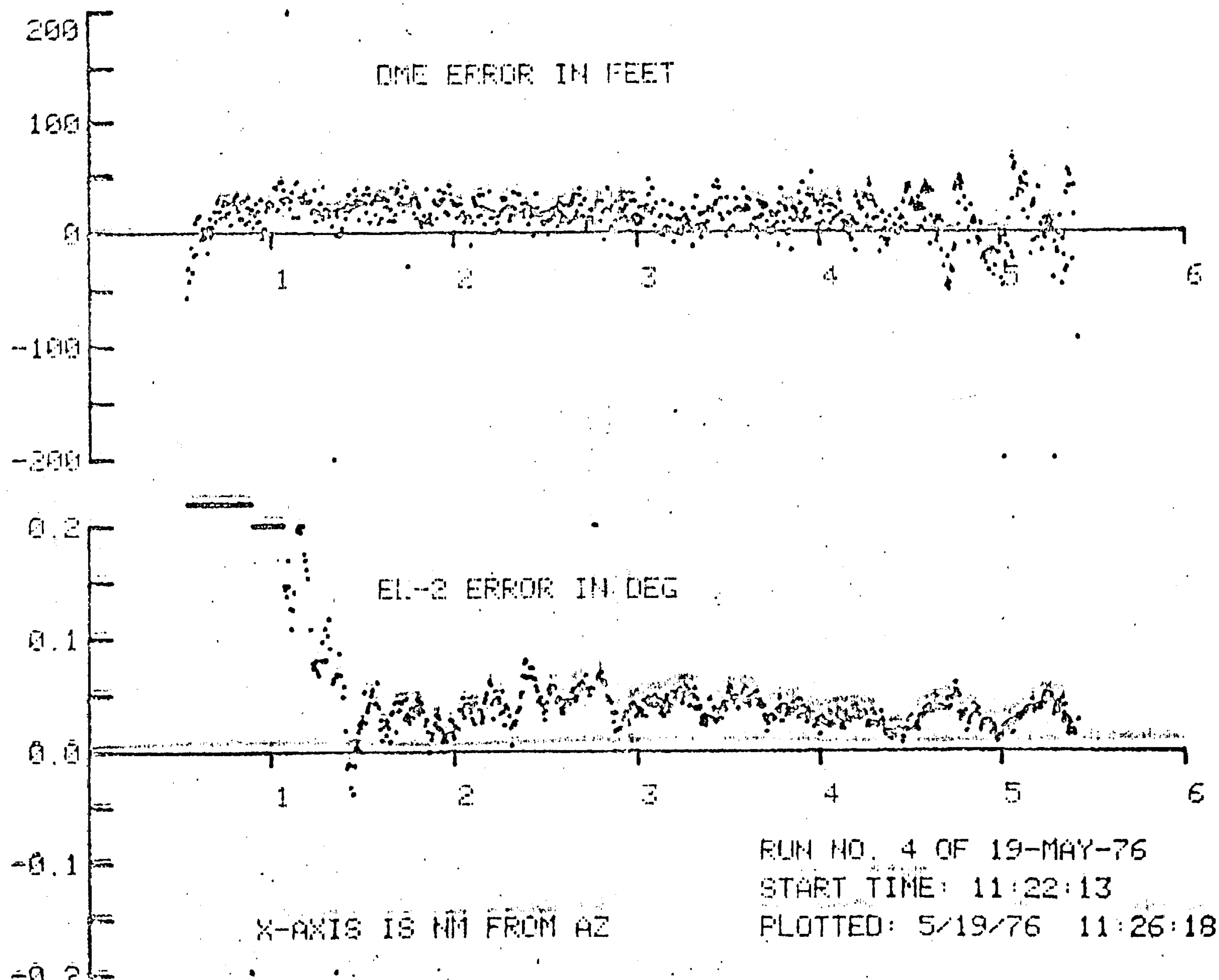


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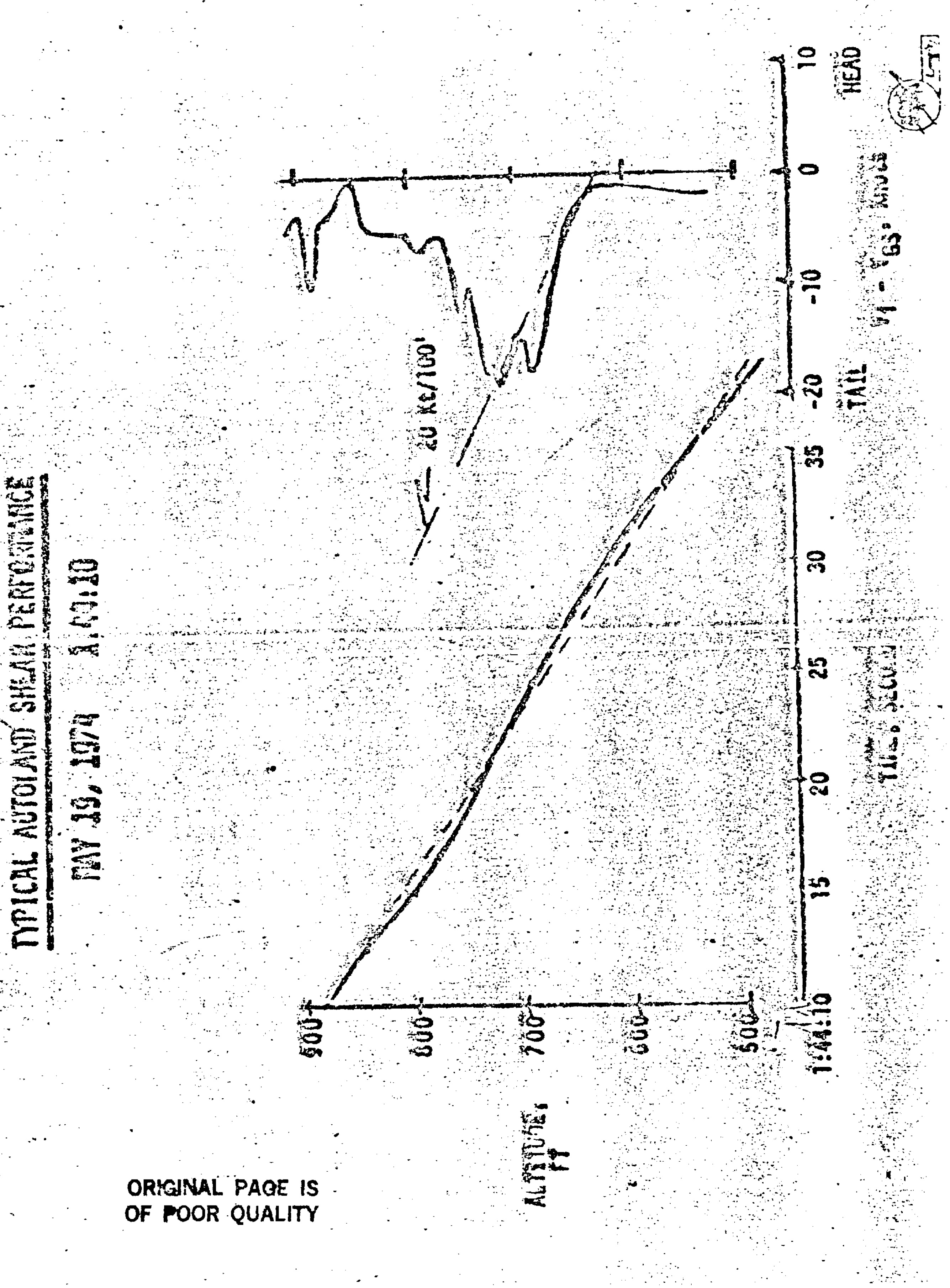


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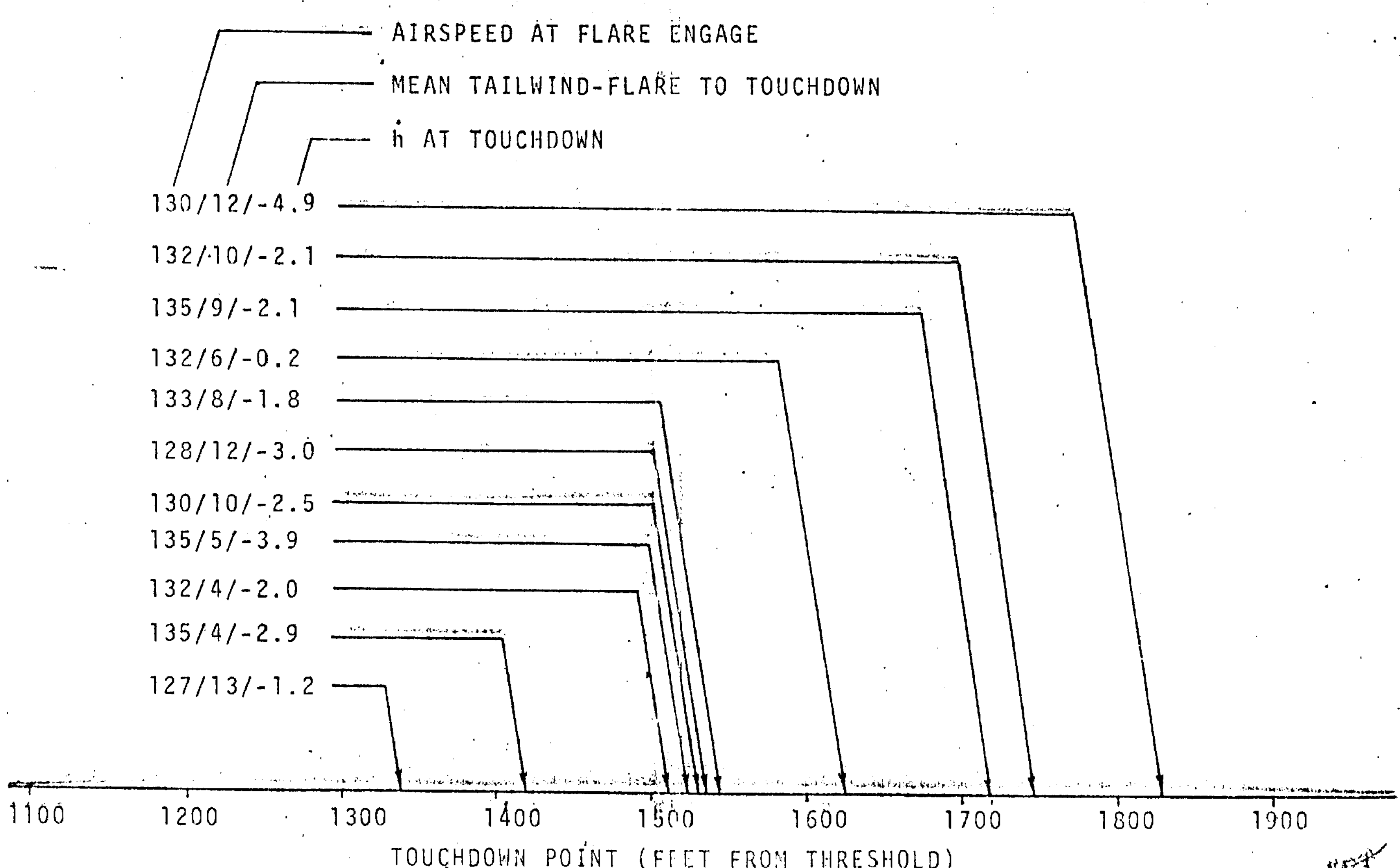
# TOUCHDOWN POINTS FROM EL2 FLARES WITH NASA 515 ON MAY 7, 1976



## SALIENT POINTS OF ICAO DEMONSTRATION

OPPORTUNITY FOR AUDIENCE TO WITNESS MLS PROOF-OF-CONCEPT

MLS AREA COVERAGE/PRECISE CURVED NAVIGATION PATHS

SMOOTH TRANSITION TO FINAL APPROACH

SHORTER FINAL APPROACH CAPABILITY DUE TO MLS ACCURACY

COMPATIBILITY OF ADVANCED DISPLAY CONCEPTS WITH MLS

SUCCESSFUL DEMONSTRATION UNDER POOR WIND ENVIRONMENT

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# APPENDIX P

SAMUEL A. MORELLO

# DISPLAY OBJECTIVES

II. IMPROVED APPROACH AND LANDING CAPABILITY IN ADVERSE WEATHER

B. EFFECTIVE COMBINATIONS OF DISPLAYS, AUTOMATIC CONTROLS, AND PROCEDURES FOR PERFORMING PRECISION APPROACH AND LANDING OPERATIONS UNDER POOR VISIBILITY CONDITIONS:

1. EXPLORE AND DEFINE APPROACH AND LANDING DISPLAY REQUIREMENTS IN TERMS OF DATA SOURCES, TECHNIQUES FOR DATA PRESENTATION AND REDUNDANCY OPTIONS.

3. INVESTIGATE FLIGHT CONTROL CONCEPTS AND OPERATING PROCEDURES TO IMPROVE HANDLING QUALITIES, FLIGHT PATH PRECISION, AND PRODUCTIVITY OF AIRBORNE OPERATIONS.

4. EXAMINE CRITICAL ELEMENTS OF THE AIRBORNE SYSTEM, INCLUDING THE CREW, DISPLAYS, AUTOMATIC CONTROL AND NAVIGATION SYSTEMS, AND DEFINE HARDWARE AND SOFTWARE TECHNIQUES, REVERSION MODES, AND VALIDATION AND MONITORING REQUIREMENTS LEADING TO IMPROVED RELIABILITY OR SYSTEM SIMPLIFICATION.

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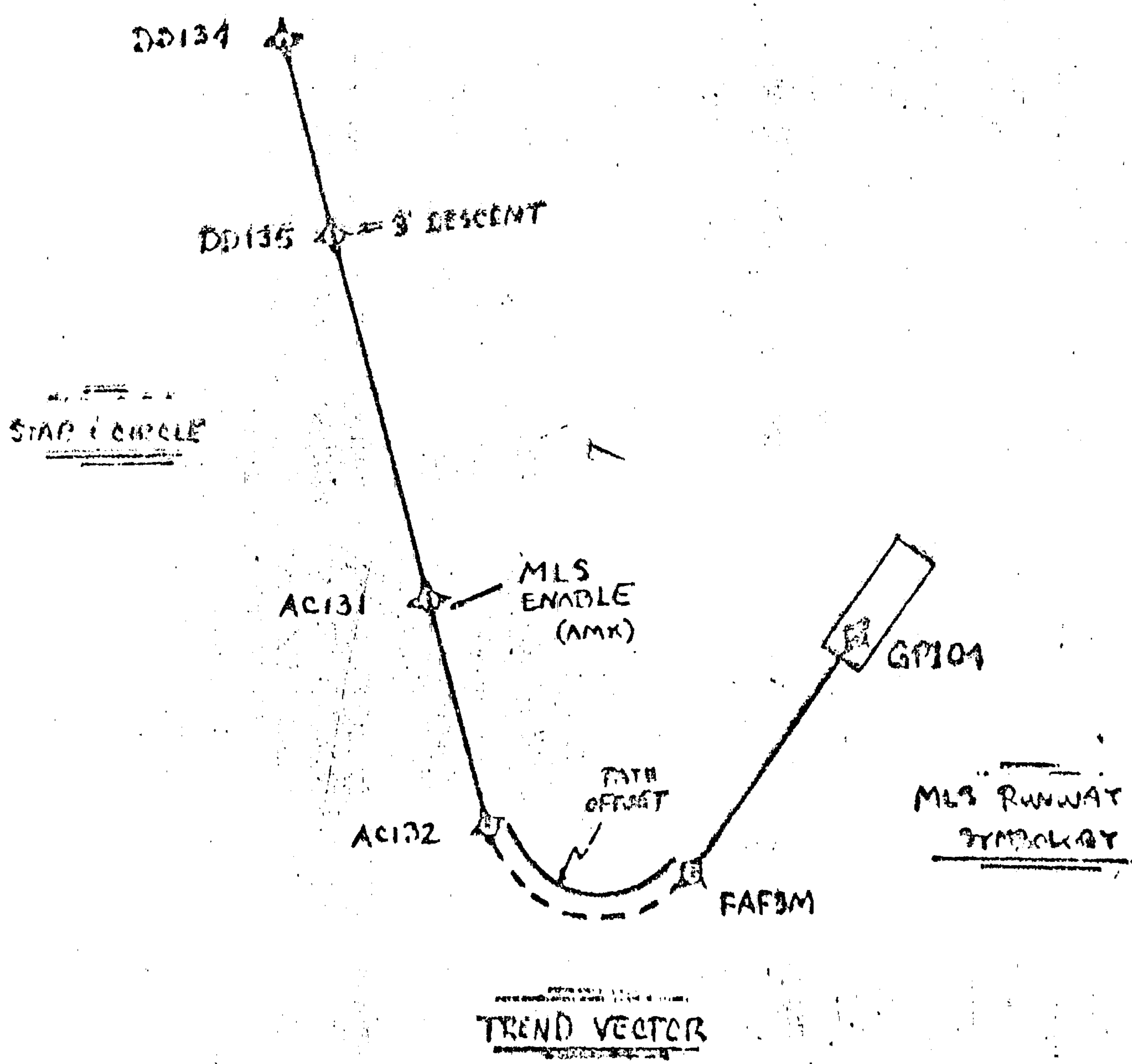
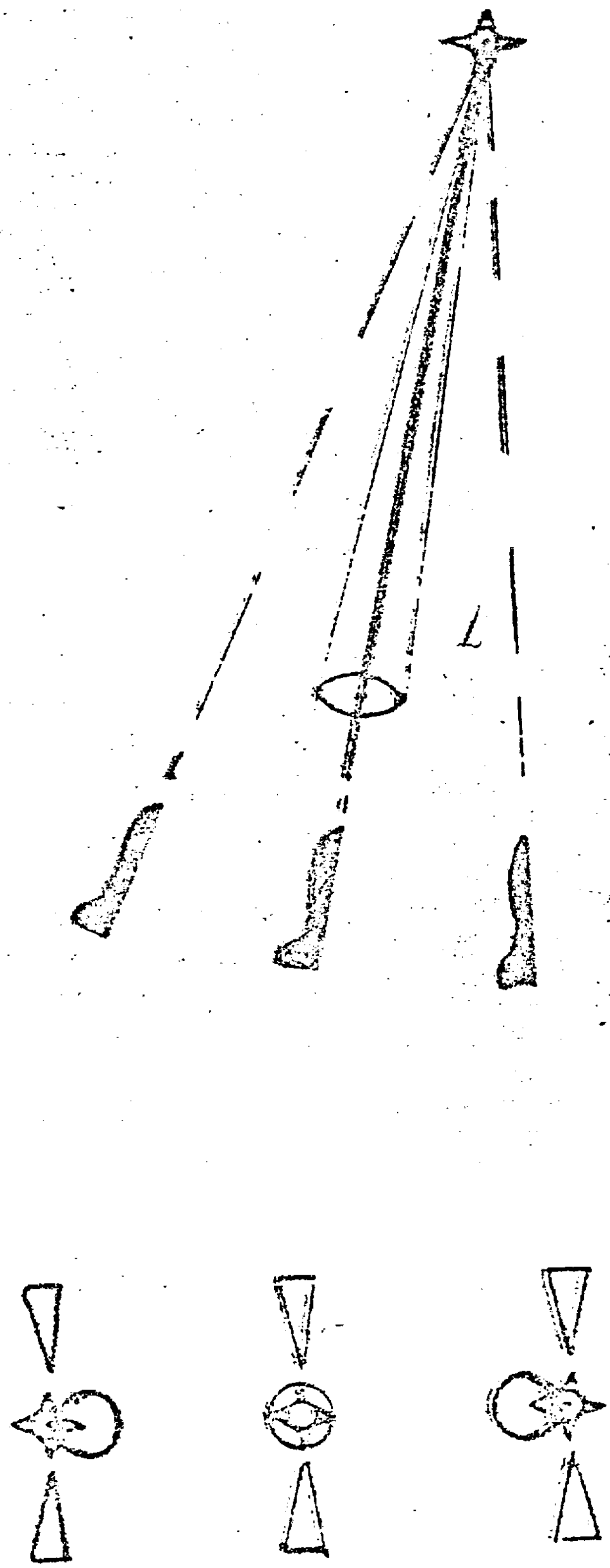
2.

# STAR AC044


DD134
DD135
3° DESCENT
STAR CIRCLE
AC131
MLS
ENABLE
(AMX)
GM104
PATH
OFFSET
AC132
FAF3M
MLS RUNWAY
SYMBOLOGY
TREND VECTOR



STAR & CIRCLE SYMBOLOGY

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# APPENDIX Q

The most important questions which Captain Larry DeCelles feels that the TCV Program will need to resolve.

1. Will mode annunciation and failure warning constitute an acceptable basis for enabling the pilot to monitor the autoland system or will it be necessary to provide adequate instrumentation for all phases of the approach and landing, including, of course, de-crab, flare, touchdown, and roll out?

2. If adequate instrumentation for all phases of approach and landing is required, can it be provided by instrumentation which will not enable the pilot *manually* to perform the automated function?

3. If the required instrumentation must enable the pilot manually to perform the automated function, will it be acceptable to accomplish this requirement by providing *command* (i.e., flight director) guidance in lieu of adequate *situation* data?

4. If presentation of situation data for manual control is necessary, can this data be displayed on a smaller than real world *scale*? If so, what is the minimum adequate ratio between the scale of the display and the scale of the real world as seen through the cockpit windshield?

5. If the instrumentation required for monitoring the autoland operation is displayed on the "*head down*" instrument panel, will the pilot be able to acquire and maintain the *proficiency and confidence* essential for relying upon the display when external visual reference is either nonexistent or inadequate?

6. Aside from the five foregoing questions, will a "head down" display provide adequate assistance to the pilot during the period of <u>transition</u> from instrument to visual flight when the external visual reference is inadequate for vertical guidance?

# APPENDIX R

AMOS A. SPADY

A. HUMAN FACTOR ELEMENTS THAT CONTRIBUTE TO EFFECTIVE FLIGHT MANAGEMENT OPERATIONS:

1. INVESTIGATE COMBINATIONS OF AUTOMATED FUNCTIONS AND PILOTING TASKS THAT COMMAND MAJOR CREW ATTENTION, ENTAIL EXCESSIVE WORKLOAD, OR REQUIRE SPECIAL TRAINING
2. EXPLORE CRITICAL INFORMATION NEEDS AND DECISION PROCESSES FOR CREW INTERCEDANCE DURING MAN/MACHINE/ENVIRONMENT INTERACTIONS, INCLUDING TRANSITION TO OUTSIDE CUES
3. EVALUATE DISPLAY REQUIREMENTS, INCLUDING FORMAT, FIELD OF VIEW, MOTION CUES, AND REAL-WORLD PERSPECTIVE, FOR APPROACH, LANDING, ROLLOUT, AND HIGH-SPEED TURNOFF
4. EXPLORE SIMPLIFIED COMPUTER-ADDRESS TECHNIQUES, INCLUDING METHODS FOR DIRECT ENTRY OF NAVIGATION WAY-POINT DATA INTO A DISPLAY

B. EFFECTIVE COMBINATIONS OF DISPLAYS, AUTOMATIC CONTROLS, AND PROCEDURES FOR PERFORMING PRECISION APPROACH AND LANDING OPERATIONS UNDER POOR VISIBILITY CONDITIONS

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I. BASIC HUMAN FACTORS

- o SENSORY MECHANISMS
- o RESPONSE MECHANISMS
- o INFORMATION PROCESSING
- o COMMUNICATIONS AND LINGUISTICS
- o STRESS AND WORKLOAD

II. ANALYTICAL APPROACHES TO DISPLAY DESIGN AND EVALUATION

III. AIRLINE CREW SCAN AND PERFORMANCE MEASURES

IV. COCKPIT PROCEDURES AND RESPONSIBILITIES

V. SIMULATOR AND FLIGHT TEST OF ELECTRONICS DISPLAYS FOR ADVANCED SYSTEMS

## TEST CONDITIONS

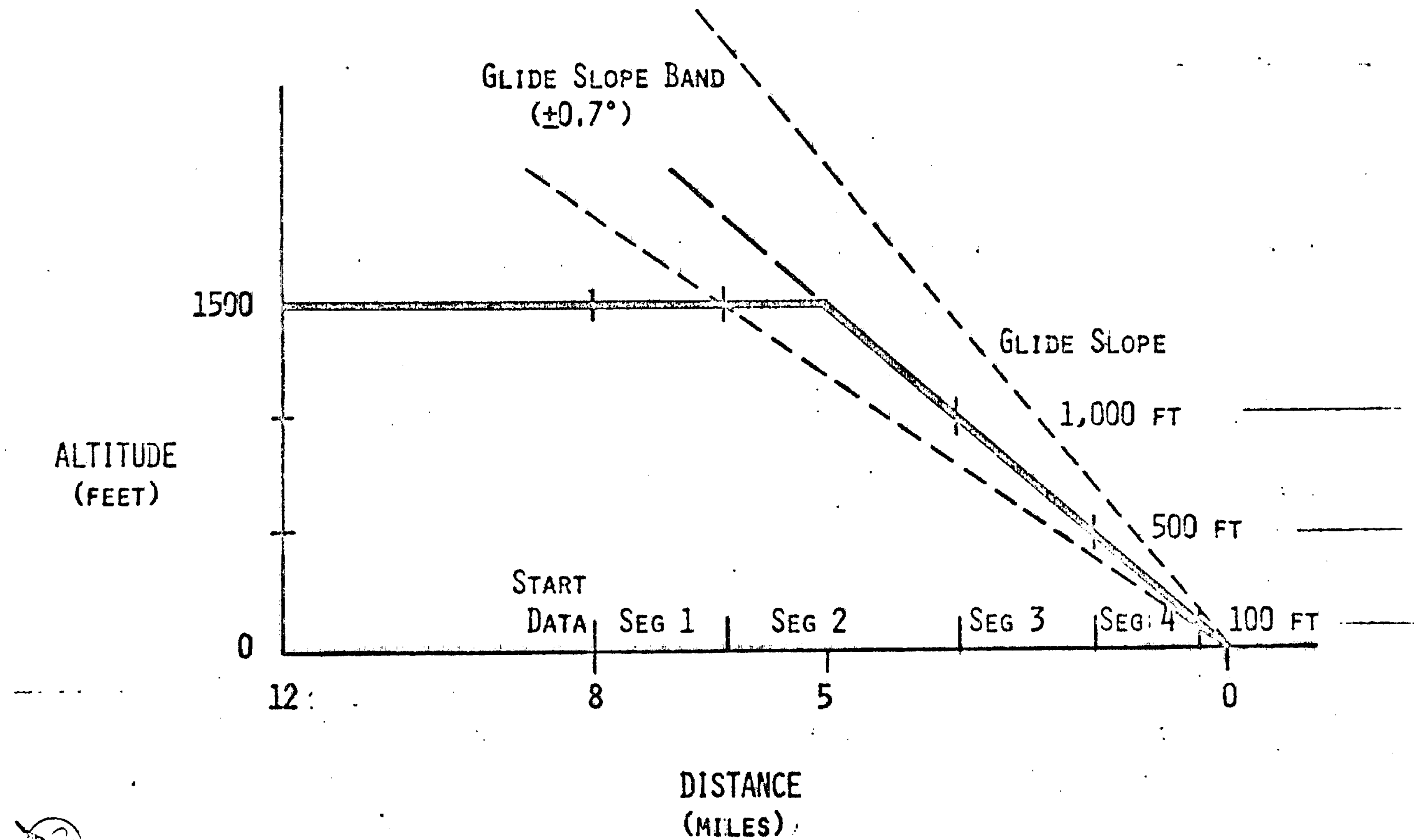
| | | | |
|---|---|---|---|
| IC 1 | MANUAL APPROACH | NO TURBULENCE | CAT II |
| 2 | COUPLED APPROACH | NO TURBULENCE | CAT II |
| 3 | MANUAL APPROACH | MAX TURBULENCE | CAT II |
| 4 | COUPLED APPROACH | MAX TURBULENCE | CAT II |

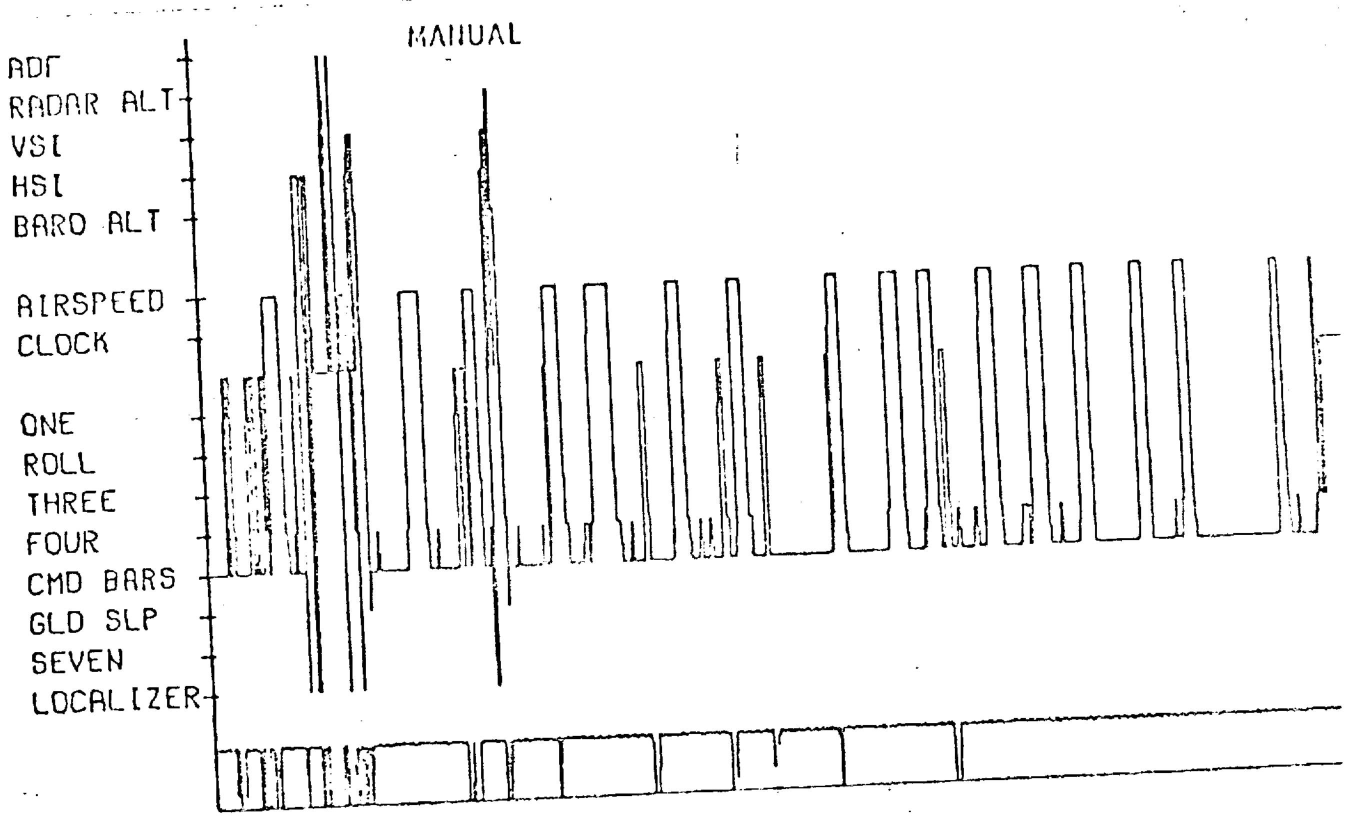
PILOTS

7 AIRLINE PILOTS
2 NASA TEST PILOTS

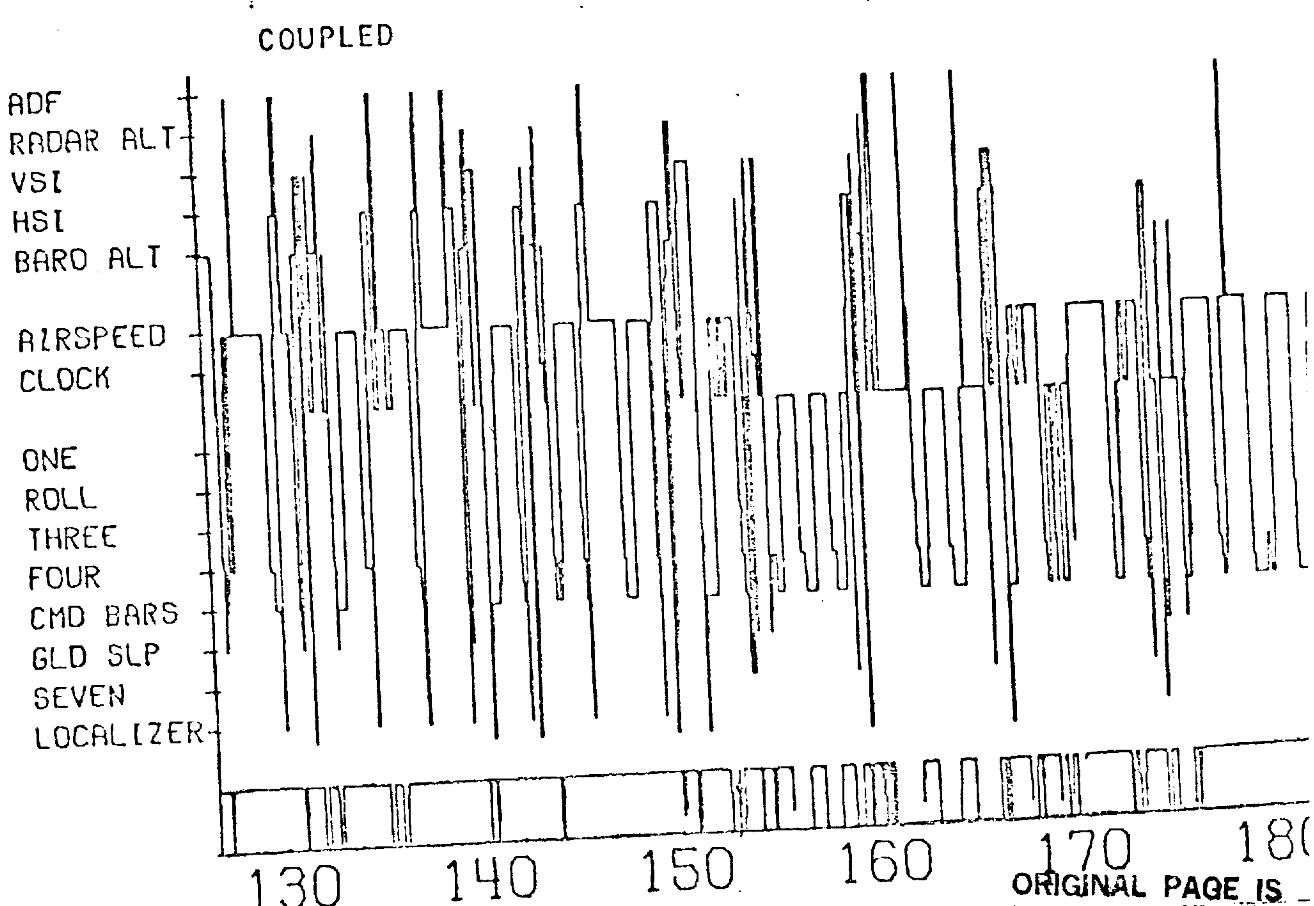
NOTE: EACH PILOT FLEW APPROXIMATELY FOUR APPROACHES FOR EACH CONDITION.

FLIGHT PROFILE






700' TO MDA (100' AGL)

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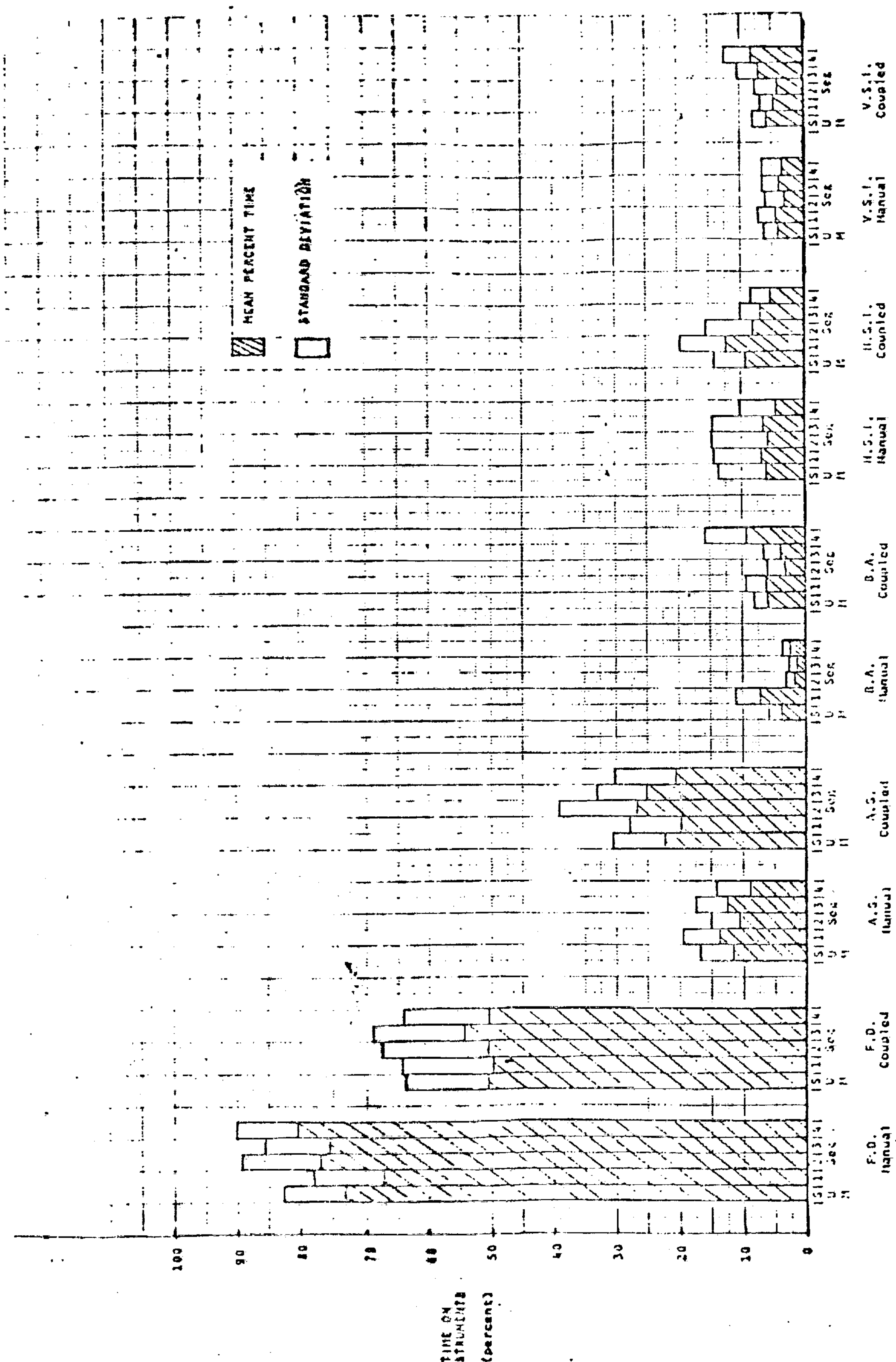
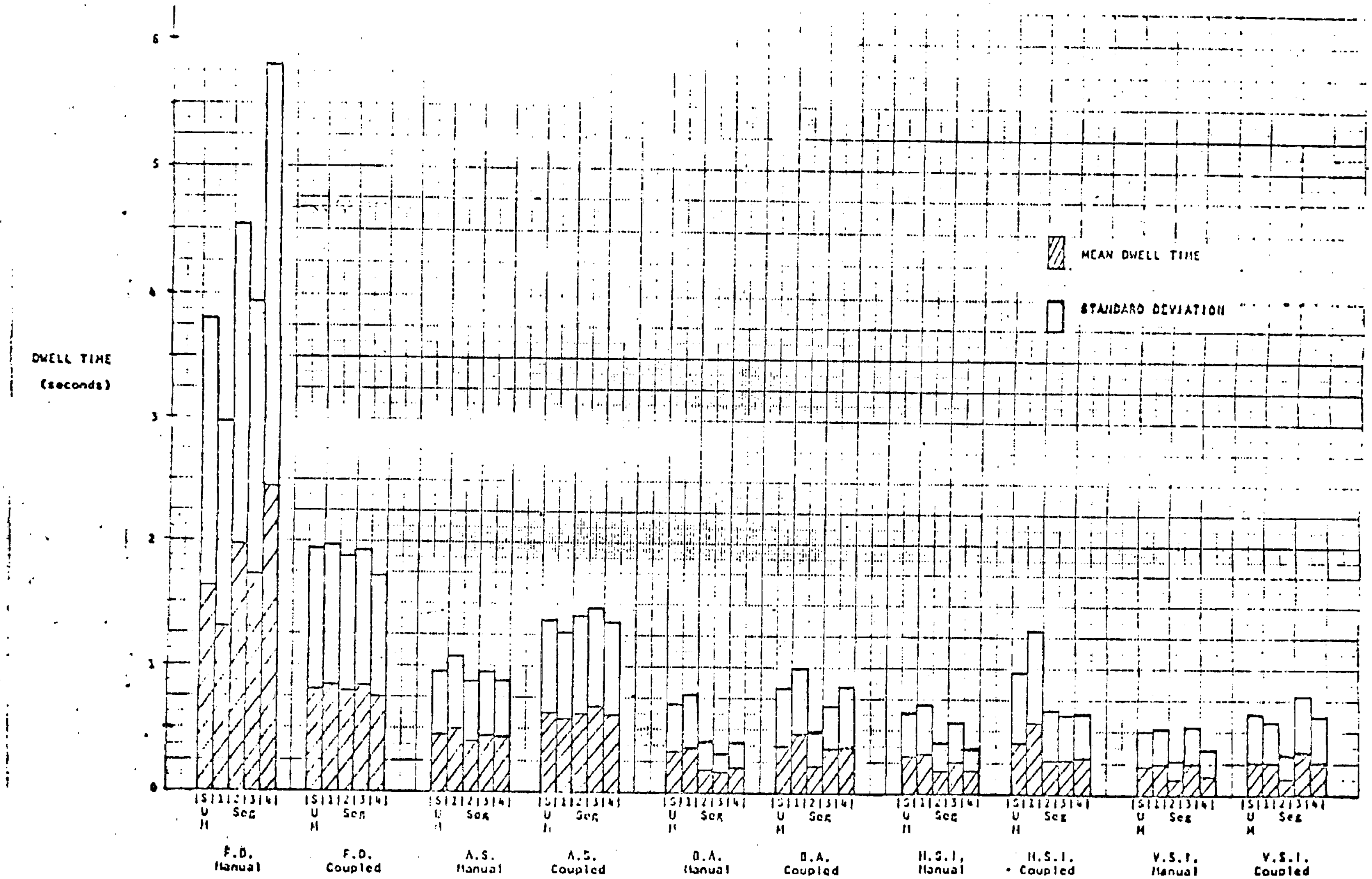
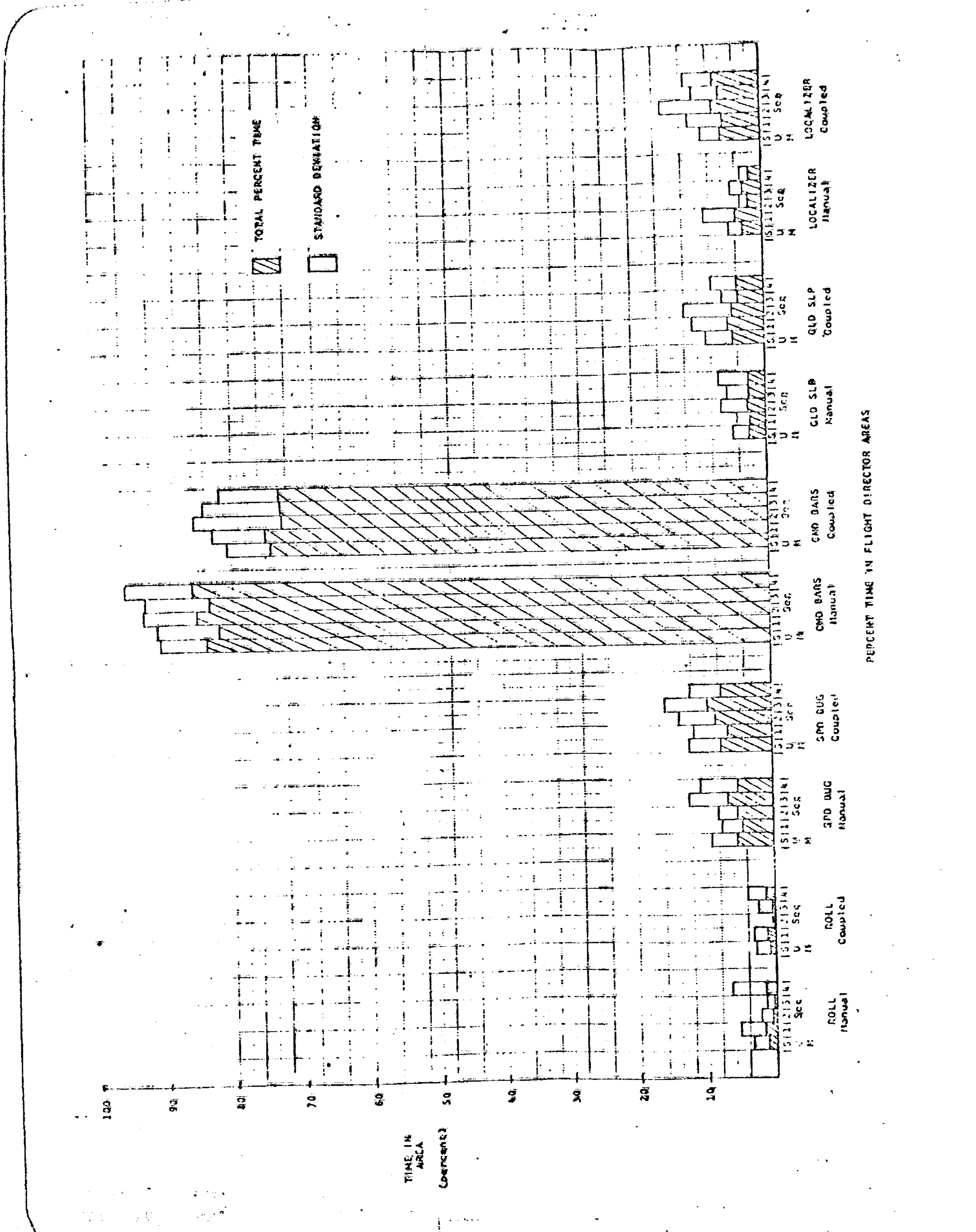
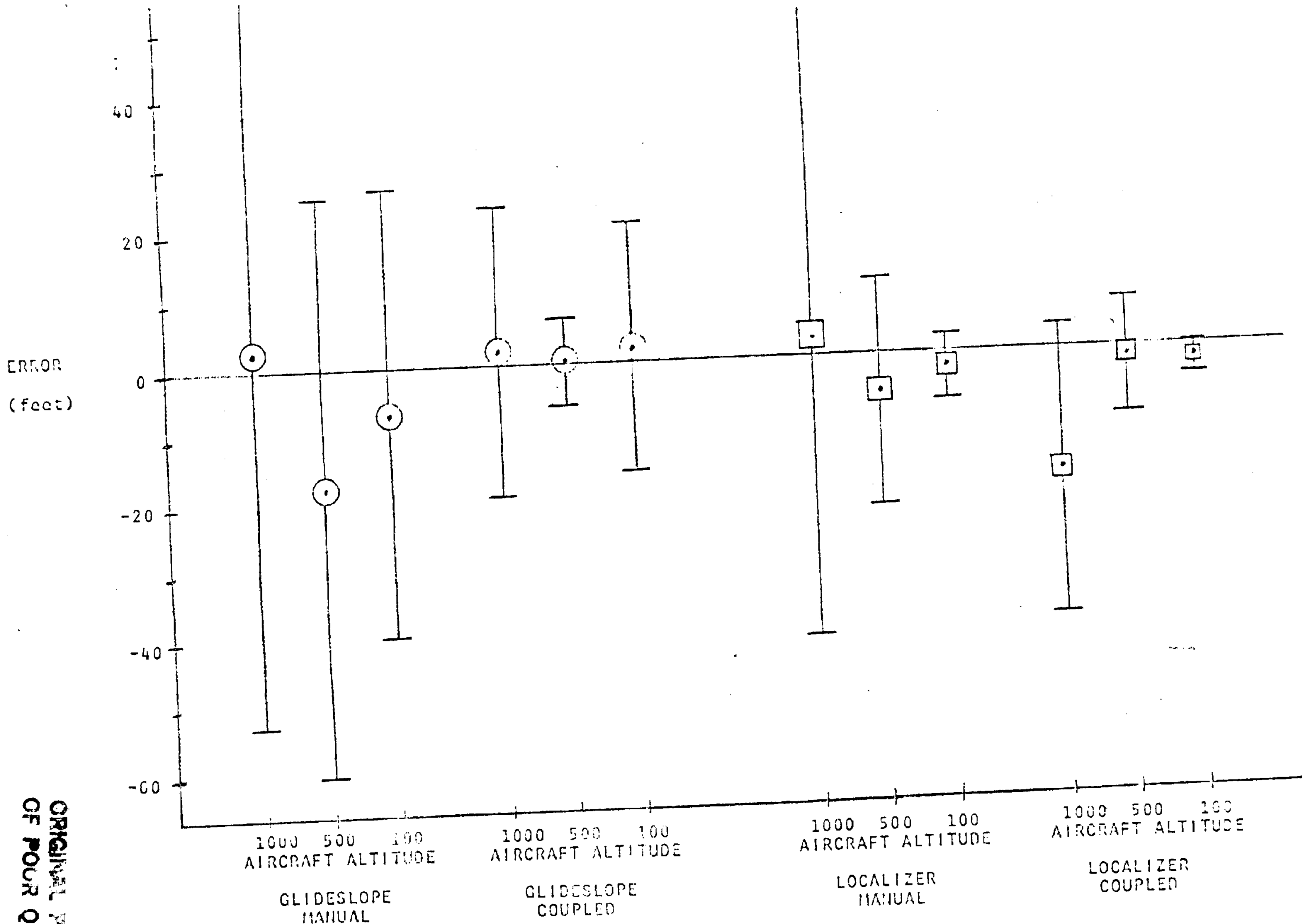



PERCENT TIME ON INDIVIDUAL INSTRUMENTS FOR MANUAL AND COUPLED ILS APPROACHES (7 pilots, 3 runs each)




DWELL TIME ON INDIVIDUAL INSTRUMENTS FOR MANUAL AND COUPLED ILS APPROACHES (7 pilots, 3 runs each)


TOTAL PERCENT TIME
STANDARD DEVIATION
TIME IN AREA (percent)
100
90
80
70
60
50
40
30
20
10
ROLL Manual
ROLL Coupled
SPD BUG Manual
SPD BUG Coupled
CMD BARS Manual
CMD BARS Coupled
GLD SLP Manual
GLD SLP Coupled
LOCALIZER Manual
LOCALIZER Coupled
PERCENT TIME IN FLIGHT DIRECTOR AREAS




MEAN & STANDARD DEVIATION OF GLIDESLOPE AND LOCALIZER ERROR
FOR AIRCRAFT AT 1000, 500, AND 100 FT. ALTITUDE

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FUTURE AIRLINE WORK

- OUT OF THE WINDOW (VITAL II)
- TRANSITION BETWEEN INSTRUMENT PANEL AND OUT OF WINDOW
- CO-PILOTS SCAN PATTERN
- EMERGENCIES

# VISUAL INFORMATION TRANSFER DURING AIRCRAFT CONTROL
## (PROPOSED FROM BRAG)

- EXPANDS WORK BEGUN UNDER GRANT NSG 1211 TO UNIVERSITY OF ROCHESTER
- DEVELOPS METHODS OF ANALYZING OCULOMETER DATA
  - INPUT DEPENDENT
  - LAG TIME CORRELATION
  - MONITORING vs. CONTROL
  - CONTROL STRATEGIES
  - WORKLOAD
  - FACTOR ANALYSIS

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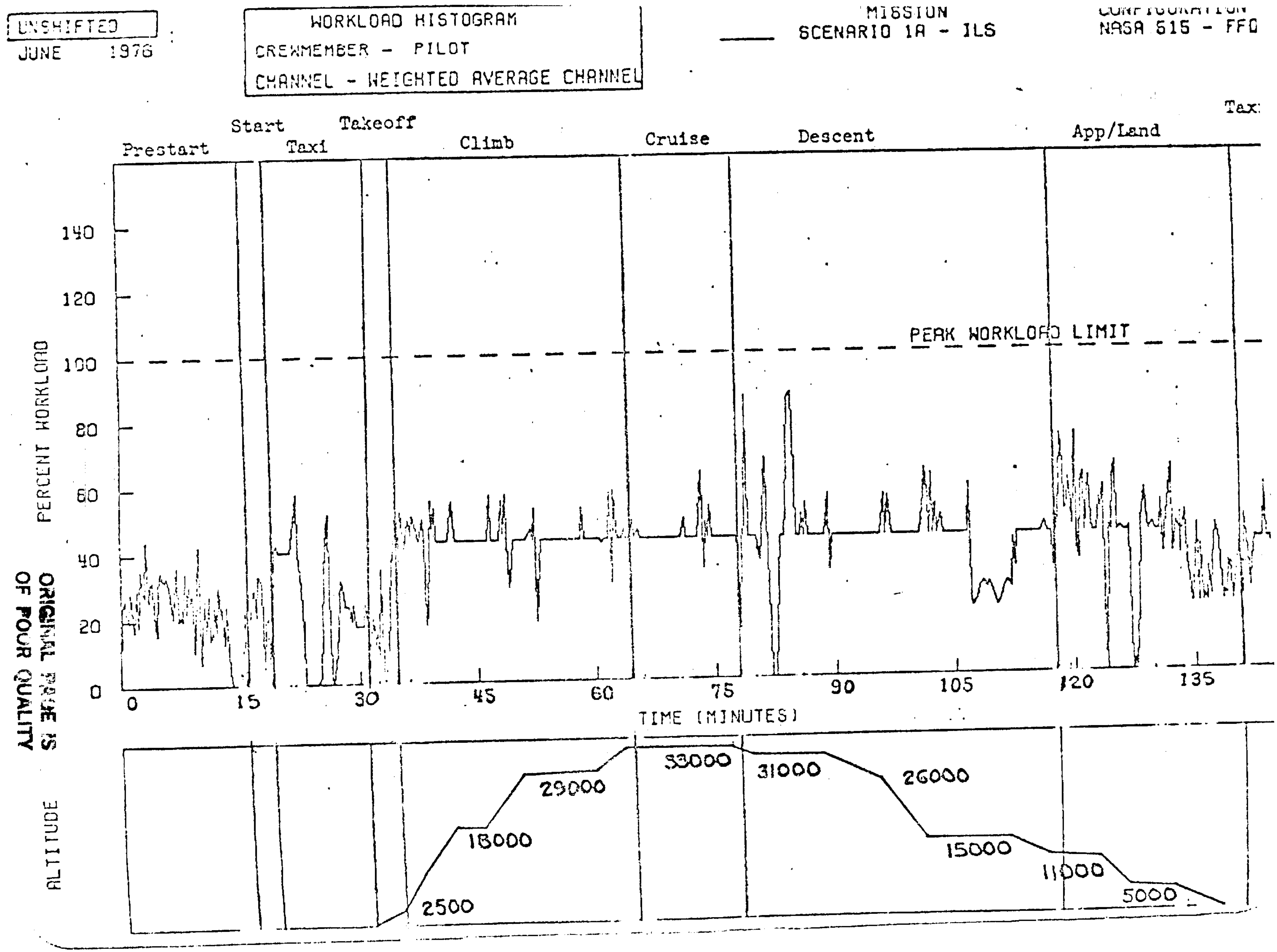
# HONEYWELL WORKLAOD STUDY

INVESTIGATORS: DR. M. KREBS, PSYCHOLOGY
DR. T. CUNNINGHAM, E.E.

PURPOSE:

- INVESTIGATE IN DETAIL THE CORRELATION BETWEEN WORKLOAD AND PUPIL DIAMETER
- INVESTIGATE THE RELATIONSHIP BETWEEN CONTROL INPUTS AND SCAN

BACKGROUND: PREVIOUSLY REPORTED IN FINAL REPORT FROM INITIAL PHASE - CR-144951


UNSHIFTED
JUNE 1976
WORKLOAD HISTOGRAM
CREWMEMBER - PILOT
CHANNEL - WEIGHTED AVERAGE CHANNEL
MISSION
SCENARIO 1A - ILS
CONFIGURATION
NASA 515 - FFD
Prestart
Start
Taxi
Takeoff
Climb
Cruise
Descent
App/Land
Tax
PEAK WORKLOAD LIMIT
PERCENT WORKLOAD
0
20
40
60
80
100
120
140
0
15
30
45
60
75
90
105
120
135
TIME (MINUTES)
ALTITUDE
2500
18000
29000
33000
31000
26000
15000
11000
5000
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UNSHIFTED
JUNE 1976

WORKLOAD HISTOGRAM
CREWMEMBER - CO-PILOT
CHANNEL - WEIGHTED AVERAGE CHANNEL

MISSION
SCENARIO 1A - ILS

CONFIGURATION
NASA 516 - FF